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THE LATEST TYPE OF CAR. THE KOBÜSCH-WAGENHALS STEAM MOTOR COACH.

THE KOBUSCH-WAGENHALS STEAM MOTOR COACH.

IN the effort to meet the present imperative demand for a satisfactory railway motor coach a rather large number of constructions have been developed of late. Through the courtesy of the St. Louis Car Company we are enabled to present a steam motor coach which has just been completed in its Baden plant. This is a steam coach, and an inspection of its construction as well as observation of its performance in operation gives one the impression that it is just about what is being sought for.

The design and arrangement of its motive power features have been developed by Mr. W. G. Wagenhals, who, in partnership with George J. Kobusch, president of the St. Louis Car Company, has been attending to the first construction which has just been completed. The accompanying photographic reproductions afford a very good idea of the essential points, drawings of which we hope to present later on.

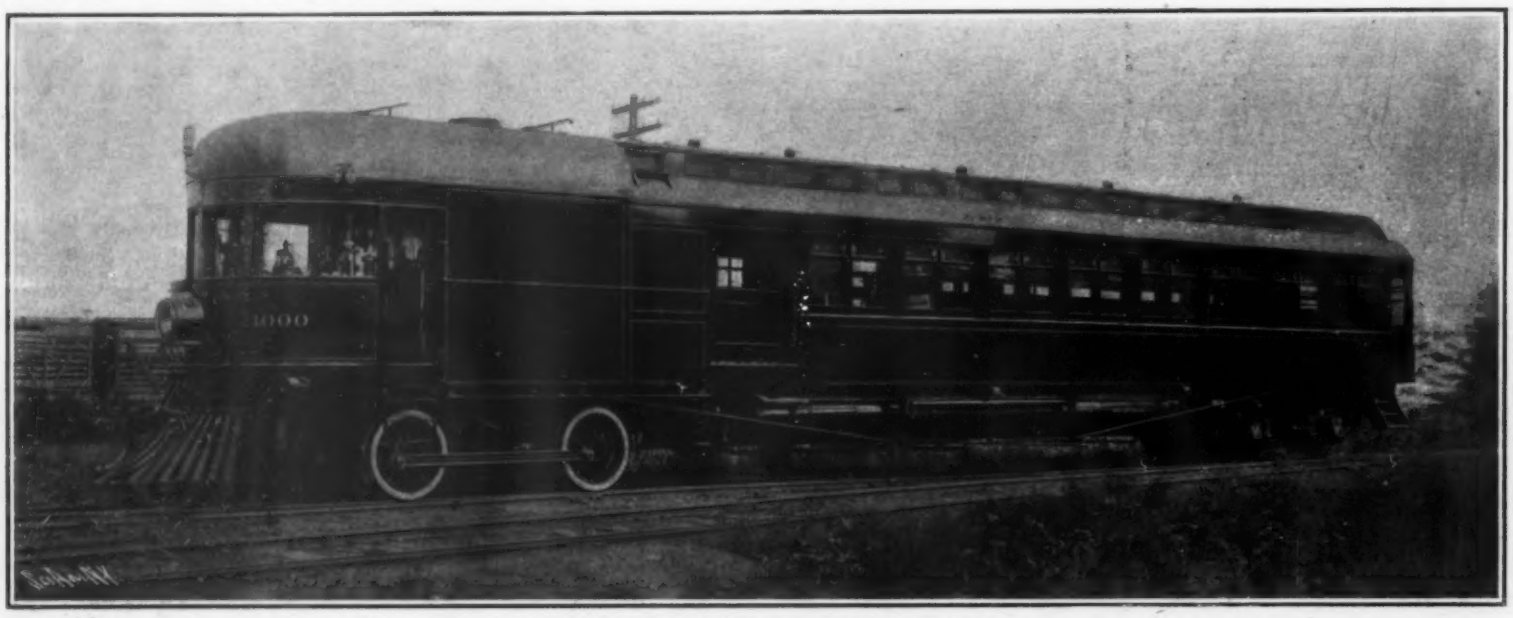
Regarding general particulars first; the coach is 82 feet 6 inches in length and has a total weight of 178,560 pounds, 115,600 of which is at the motor truck end. Height, from rail to top of stack, 15 feet 2 inches; width, 10 feet over all. The underframing is of steel and the body construction and fitting is that usual with high grade railway coaches so far as the passenger and baggage compartments are concerned. That portion of the body which incloses the boiler and "motoneer's" compartment, however, is constructed of steel. The coach seats fifty-two persons in the main compartment, and twelve in the smoking compartment. Ahead of the latter is a baggage compartment ten feet in length, while the remaining twelve feet is assigned to motive power uses.

In this latter compartment a marine type, water tube boiler occupies the space immediately ahead of the baggage compartment and over the motor truck. This boiler is of the square, torpedo boat type, measuring 77 inches in width and breadth. It has 1,215 square feet of heating surface, 43.5 square feet of grate area and carries a working pressure of 250 pounds per square inch, though it is built for a cold water test of 500 pounds. It is fired with crude oil through five burners of a special design. One thousand gallons of this oil are carried in a tank underneath the car body. In this tank the oil is heated by a portion of the exhaust steam and a pressure of air, obtained through a reducing valve from the main reservoir of the brake system, forces the oil up to the burners, where it is sprayed by either steam or air, or both, as may be desired. Owing to the high steam pressure as well as the desirability of easy feed control a marine type boiler feed pump is used instead of an injector. Two thousand gallons of water are carried in two tanks also under the body of the car and the feed water passes through heating coils at the top of the boiler before entering the boiler proper. In addition to the boiler and its attachments, the compartment contains a Westinghouse 9½-inch pump and a complete E-T brake equipment. The throttle and reverse levers are located most conveniently for the motoneer, while the other controlling devices, such as that of the feed water pumps, etc., are all within easy reach.

The main steam pipe runs from the boiler (overhead) to the front of the compartment, where it is turned down and runs through the floor to a casting which is the female part of a flexible joint. A similar joint is near the forward end of the motor truck center casting. In the length of pipe which connects these two flexible joints is an expansion joint. Trial has shown this arrangement to be most satisfactory, as there is no escape of steam under any condition of swiveling and there appears no indication of any weakness developing. The guide just ahead of the end sill provides for retaining the reach rod to the link motion in line during the rises and falls of the truck with respect to the car body. The forward end of this reach rod is merely a box guide through which is passed a bar, curved to the radius of the distance to the truck center. This bar is pivoted at one end and at the other end attaches to the lower arm of the reverse lever. This arrangement provides a positive control of the link motion entirely unaffected by any movement of the truck with respect to the car body.

The most striking feature of the car, however, relates to the motor truck, the arrangement of which is not only most unique but has been so cleverly worked out as to create a most favorable impression of the idea. Instead of following locomotive precedent Mr. Wagenhals has really taken street car precedent and practically merely exchanged a steam motor for the electric motor which is geared to one axle. Side rods have been added to utilize all four wheels and an inspection of the cuts will show simplicity and workmanlike character of the essential arrangement. A double cylinder, piston valve, 11 by 12 inches, 275-horsepower engine has the frame of its cylinder end hung on a single point spring suspension just back of the truck center casting. At the other end, the engine frames are extended beyond the crank shaft so as to rest on and be supported by the axle of the forward wheels. This affords a three point suspension for the engines, while a still further extension of the engine frames enables the two to be rigidly connected by means of the heavy shouldered bolt. A pinion on the crank shaft meshes with a gear wheel on the axle, in the same manner as is practised with electric motors. Both engines are inclosed in crank cases so as to be self-oiling as well as protected from dust, etc., and the gears also run in a case. The oil cups of the other parts are located outside the truck frame and reach their particular bearings by means of small pipes. The wheels are 42 inches in diameter and with the present size of pinion and gear a tractive effort of 8,000 pounds, or a speed of 40 miles per hour is secured. The exhaust is used to heat the coach and the fuel oil, though it is directed out the stack when not required for these purposes. The truck center casting and frames are of cast steel and the 7 by 10 inch axle bearings are equipped with locomotive type boxes and cellars. The trailer truck is of the standard M. C. B. four-wheel type, with its center 53 feet from that of the motor truck.

In operation one is struck particularly with the entire absence of vibration due to the working of the engine. This is, of course, due to the divorce of the motor truck from other than a center casting connection with the car. Also the large boiler capacity enables the engine to be worked to its full capacity under all conditions and the engines are of a size which lifts the car into speed in a surprisingly quick manner. Another point which impresses one is that only three or four easy disconnections are necessary to enable the truck to be run out from under the car for repair or exchange with another truck. Within a few days the car will be sent on a demonstration trip around the country, in the course of which it will be placed on exhibition in the depots at the large railway centers. Following this the present car will be put into regular service on the Missouri Pacific Railway.



THE KOBUSCH-WAGENHALS STEAM MOTOR CAR.

DIRIGIBLE AIRSHIPS.

By COUNT VON ZEPPELIN.

A BALLOON that is motionless with respect to the surrounding air shares all the latter's movements, which are not small. In a calm the air is moving with the resultant of the earth's velocity in space and the rotational velocity of its surface and a hurricane represents only a comparatively slight deviation from this average velocity.

A dirigible or automobile airship can propel itself through the surrounding air at a speed limited to the velocity at which the effective propelling force equals the air resistance, which depends on the size and shape of the vessel.

All designers agree that an airship must be an elongated solid of revolution but some prefer a cylindrical, some the tear shape used by Santos Dumont and Lebaudy. This form, or in general a form with a blunt bow immediately followed by a gently tapering after part, is suggested by the forms of birds, fishes and ships. Some even recommend imitation of the bird's flight. It would be as sensible to build an automobile in the form of a mechanical greyhound. Before blindly imitating nature we should consider whether our object is the same as hers. The strongest and hence the broadest part of a bird's body is at the place of attachment of the wings, and a fish needs a gently tapering, flexible after part, in order to employ its caudal fins effectively. In the airship both of these considerations are subsidiary to the requirement that the cross section shall be as small and the internal capacity as large as possible. Water waves travel about 4 meters (13 feet) per second, as may be ascertained by noting the time which the swell of a boat at a known distance occupies in reaching the shore, or by observing how the swell runs ahead of the slowly-moving swan, falls behind a fast steamer, and keeps even pace with a boat going about nine miles an hour. Now, the shorter the bow of the fast steamer is, the smaller is the number of such overtaken waves that impede its progress, and the longer the portion tapering from the maximum cross section to the stern is, the more numerous are the waves which, so to speak, squeeze it forward. Until ten years ago, therefore, the belief prevailed that a long amidship section with parallel sides involved loss of speed.

Helmholtz, however, has pointed out that the air which envelops an airship, unlike the water surrounding an ordinary vessel, can escape in every direction, and that, furthermore, the speed of the airship is so small in comparison with the velocity of sound (i. é., of air waves) that difference in the density of the air may be neglected. How Helmholtz was able to pass from this explanation of the essential dissimilarity of the conditions of motion of airships and ordinary vessels to the conclusion that the two are identical, is more than I can understand, but he did so, and the advocates of the "tear shape" are supported by his great authority. I advocate the cylindrical form for airships for the very reason that their velocity is insignificant in comparison with that of air waves, yet I feel confirmed in my view by the fact that during the past ten years the straight amidship section of ocean vessels has been continually lengthened with great advantage, although the waves of displacement do affect the speed in this case.

The shape of the bow should be such that the air will be displaced by a large surface presenting no concavity in order to reduce the compression to a minimum. A semi-ellipsoid is better than a paraboloid because it is tangent to the cylinder behind it and presents no angle to increase the resistance. The stern should be shaped like the bow, because the withdrawal of a body from the air develops a resistance similar to that which opposes progression.

The carrying power of a cylindrical airship is proportional to its length and the square of its diameter. Large vessels are faster than small ones because the increase in carrying power permits the employment of motors more powerful than would be required to overcome the increased resistance even if the resistance were proportional to the surface.

But it is not. The resistance per unit area diminishes as the total surface is increased. I deduced this law from observation in 1895-6.* In 1903 Hergesell confirmed this law by experiments with pendulums having spherical bobs of various sizes. Ritter has recently attempted to disprove the law by mathematical demonstration supported by a single experiment in which only small surfaces were used. In view of the danger of falling back into the old erroneous assumption that the resistance is proportional to the

* Zeitschrift des Vereins Deutscher Ingenieure, 1895. Zeitschrift für Luftschiffahrt und Physik der Atmosphäre, 1896.

area of the surface, let us devote a little attention to the true law of resistance, which is not to be overthrown by old traditions, mathematical reasoning or the experiments of Ritter, Lössl, and Canovetti which, though otherwise admirable, were made with too small surfaces.

An air current striking a surface must be deflected to its boundaries. The succeeding particles of air encounter this deflected current so that they do not exert their full force against the surface or the air cushion that covers it, but are carried away in a direction and with a velocity which correspond to the resultant of the arriving and the deflected currents. The larger the surface is, the more rapidly is the initial mass of air forced outward, the greater is the deflection of the succeeding particles and therefore the smaller is the pressure exerted by them on the surface.

Or, let us compare two disks of 10 and 100 square inches, each divided into rings of equal area, say 1 square inch. The outer ring of the large disk is narrower than that of the small disk, consequently the particles which strike the outer ring are more readily deflected outward and the reaction is less in the first case than in the second. Hence the increase of pressure due to unit increment of area must be less for the large disk than for the small one, or the total pressure must increase less rapidly than the area.

In designing an airship the danger of sinking must be guarded against as securely as in designing an ocean vessel. Many inventors solace themselves with the knowledge that if the airship is compelled, by failure of the machinery or otherwise, to descend, it can sink slowly and land safely, like an ordinary balloon. This is sufficient for the experimental stage, but airships will be of little value until they can travel long distances over wooded, mountainous, and densely populated districts and over the sea, where the gentlest descent may be fatal, as well as over the enemy's territory, where landing means captivity. As there is no motor which is not liable to frequent stoppages, the airship should have at least two independent motors.

The most effective means of propulsion is the screw propeller. Experiment has disproved the old theory that very large slowly-turning propellers give the best effect. More than ten years ago I had a (water) boat built to be driven by air propellers, in order to test my propellers and motors. I found that properly constructed propellers, which impose on the motor exactly its full normal load, show equal efficiency whether they have long blades and turn slowly or have short blades and turn rapidly, also whether they have two, three, or four blades. A speed not very different from that of the motor is advisable, because it simplifies the transmission. Small propellers are preferable because they save weight and space and need only short shafts.

Whether the airship shall be small or large, rigid or flexible, will depend on the nature of its employment and the corresponding requirements in regard to safety, speed, load and radius of action.

Lebaudy's war airship, the best representative of the flexible system, attained in 1904 an average speed of 11 meters per second (36.1 feet per second, or 24.6 miles per hour) and a maximum speed of 11.8 meters per second (38.7 feet per second or 26.4 miles per hour) carrying sufficient benzine for 11 hours. As each Lebaudy is larger than the last with a relatively lighter motor it appears probable that a 12 hours' flight with four men at a speed of 12 meters per second (39.4 feet per second or 26.8 miles per hour) will soon be accomplished. Major von Parseval may possibly achieve such a result still sooner. What of it? A flexible airship of this type is too uncertain to attract many aeronauts. Above all, it has only one motor and the addition of a second independent motor with its propellers would necessitate an increase in size that would seriously affect the speed and duration of flight.

Furthermore, the shape of the gas bag can be preserved only by keeping the gas under constant pressure by means of an inner bag, or "ballonet," inflated with air by a pump driven by the motor or preferably by an independent motor. If the motor stops or the air pipe leaks the airship changes in form, refuses to obey the helm and is in a dangerous plight.

Another source of danger is the single gas bag made necessary by this maintenance of internal pressure. A bullet or a branch of a tree may tear the bag, let out all the gas and cause a catastrophe.

Flexible airships can serve only for sport, or for military or scientific purposes which justify the taking of risks. In war they would be very useful, notwithstanding their small radius of action. But the employment of flexible airships of only twelve or even twenty-four hours' flight in field operations—as distinguished from sieges—necessitates the assignment to each vessel of a company almost equivalent, in officers, men, horses, and wagons, to a field battery, and consequently entails great expense. For naval operations such airships could be used only near the coast.

The only representative of the rigid system is my own airship. It has a rigid hull, the shape of which is not affected by the degree of distension of the gas cells which it contains. This construction does away with the objections mentioned above and, in particular, it allows a second system of propelling mechanism to be placed at such a distance from the first system that they do not interfere, without necessitating any increase in the cross-section of the hull and, therefore, without increasing the resistance to progression. I reached this result in the following way:

In the first place, I calculated how long an approximately cylindrical hull of very small diameter could be constructed that would sustain its own weight and the weight of its car, crew, and machinery. The limit of length is reached when a further increase involves an increase in weight (used in stiffening the long cylinder to prevent bending under the load on the middle point) greater than the increase in buoyancy given by the added length. If this limit has been reached and a second motor, etc., are then added the additional volume of gas required to sustain them can be accommodated only by increasing the diameter of the cylinder and consequently diminishing the speed. To avoid this I connected, end to end, two such cylinders, each carrying its own car and machinery. Thus I doubled the length of the airship without enlarging its cross-section and provided it with two entirely independent propelling systems, either of which could be used alone for moderate speeds.

The requisite rigidity is given by a series of rings, stiffened by transverse braces. This construction necessitates the division of the gas capacity into a number of cells which, like the water-tight compartments of a ship, insure safety because the rupture of one does not affect the others.

The outer skin is of waterproof fabric, stretched over a metal frame. An interval is left between it and the gas cells so that the latter are not immediately affected by the unequal heating of the skin by the sun's rays and the buoyancy is fairly uniform. Variations in buoyancy cannot be entirely avoided as the airship is lightened by the consumption of benzine and made heavier by rain, snow, and hail. In the rigid system the compensation of these variations by expenditure of gas and ballast and by oblique flight can be avoided by the addition of horizontal rudders acting as aeroplanes. A great advantage of the rigid system is the possibility of fixing the propellers at the level of the center of resistance and thus avoiding the waste of energy involved in the struggle to maintain horizontal flight.

The probable speed of my airship was calculated in 1903 by Prof. Müller from the most reliable formulæ of resistance and the experimental data of Renard and others. The result was 14 meters per second with two motors, each of 50 horse-power. The speed attained in my flight of January 17, 1906, using 170 horse-power, was about 15 meters per second (49.2 feet per second or 33.5 miles per hour) which agrees well with Müller's figures.

This speed was determined from the observation, made simultaneously from the ground and both cars, that when the airship was steered approximately to windward, it remained nearly over the same point and was never driven backward. The velocity of the wind was estimated from the time which elapsed between the stopping of the motors and the landing of the airship at a point 19 kilometers (nearly 12 miles) distant, and was found to be at least 15 meters per second. When the airship was driven by the motors alternately instead of together, the speed was computed to be about 12 meters per second (39 feet per second or 26.7 miles per hour). To allow for possible error I take the speed with both motors as 14 meters per second or 50 kilometers (31 miles) per hour, and the speed with one motor as 11 meters per second or 40 kilometers (25 miles) per hour.

With a load of 3,090 kilogrammes (6,800 pounds) in addition to its own weight, the airship rose to a height of 850 meters (2,800 feet) above sea level. Hence 4,300 kilogrammes (9,460 pounds) could have been carried at the sea level. If 500 kilogrammes (1,100 pounds) are deducted for possible error and the consideration that the start would sometimes be made from an elevation of several hundred feet, and 800 kilogrammes (1,760 pounds) for crew, provisions, etc., 3,000 kilogrammes (6,600 pounds) are left for fuel. As each motor consumes 25 kilogrammes (55 pounds) per hour, the airship, using both motors, could travel 60 hours at 50 kilometers (31 miles) per hour, or 3,000 kilometers (1,860 miles). With one motor it could travel 120 hours at 40 kilometers (25 miles) per hour, or 4,800 kilometers (3,000 miles).

The objection is often made that these long flights are theoretical and have not been actually accomplished. I reply that trial trips of moderate length prove the feasibility of the longer journeys. A new ocean steamer starts confidently for China after making comparatively short trial trips.

But there is one great difference. The steamship has officers and men trained by experience in similar ships, while I am the only man who has commanded a large rigid airship, and my experience is limited to four flights of an aggregate duration of three hours.

The management differs greatly from that of a small, flexible airship. The heavy masses are not easily moved or stopped, and as the resistance offered by them to the air varies with their position in the vessel, they cause oscillations which must be checked by special devices. Vertical motion must be effected by power, to save gas and ballast and prolong the flight. Experiments with double aeroplanes like my lifting rudders have given an upward pressure of 13.1 kilogrammes per square meter (2.68 pounds per square foot) for a speed of 12 meters (39.4 feet) per second and an inclination of 15 degrees. Therefore, with my rudders, aggregating 26 square meters (280 square feet) total pressures of from 340 to 680 kilogrammes (750 to 1,500 pounds) can be obtained.

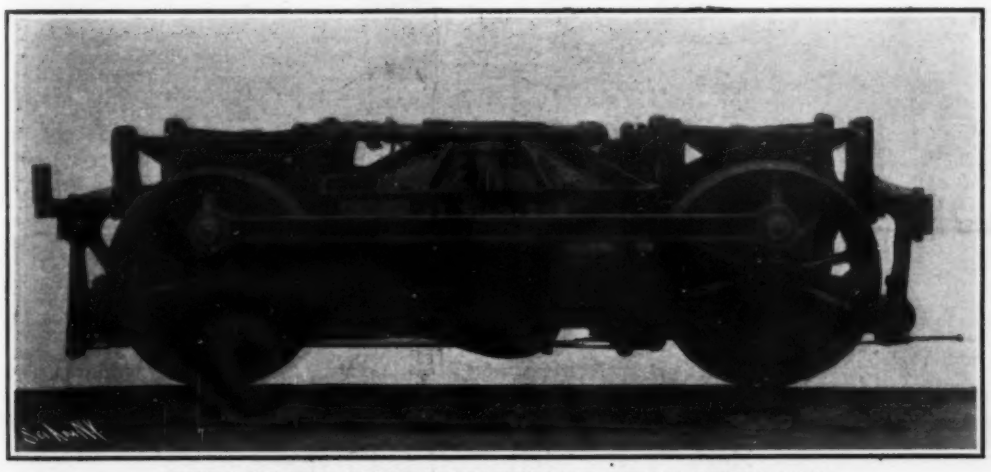
Usually only one motor would be used, to lessen the danger of both failing simultaneously and also increase the length of flight. Both motors would be used only to gain a moderately distant point as quickly as possible, or against strong head winds, to overtake a hostile airship, etc.

As the travel over the ground is the resultant, in direction and velocity, of the wind and the proper motion of the airship, the progress of the vessel, like that of a sailing ship, depends upon the wind. The sailing ship, unlike the airship, however, can beat to windward against the strongest gale, though it is motionless in a calm, when the airship goes ahead at full speed.

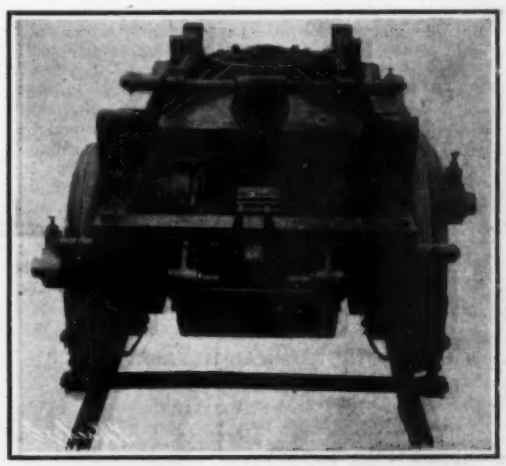
On the average, wind favors the progress of airships for these reasons: First, during half of the time the wind is directly favorable; secondly, very often when the start is made with an unfavorable wind an opposed current can be found above or one side of the straight course; thirdly, in many cases a favoring wind may be expected to spring up during the flight.

Therefore meteorologists can render immense service to aeronauts by increasing the number of observing stations, promptly disseminating information and extending the system of wind charts to the continents and to elevations of 200, 500, 800, and 1,200 meters. The knowledge of the maximum height of fog, the aeronaut's worst enemy, in different latitudes, would also be very valuable.

There is no difficulty about obtaining bearings while in sight of land that can be identified on the chart. Over the ocean the direction and rate of resultant mo-



TRUCK OF THE KOBUSCH-WAGENHALS STEAM MOTOR CAR.



LEAD END OF KOBUSCH-WAGENHALS STEAM MOTOR TRUCK.

tion may be obtained by dropping a float by day or a piece of potassium, which inflames on contact with water, by night and measuring the inclination of its apparent direction as seen from the known elevation of the airship at measured intervals of time. The speed and direction of the proper motion of the airship being also known, the velocity and direction of the wind can be deduced and the course laid accordingly. I have devised a simple instrument and a table which gives the required figures and compass points at a glance. The latitude and longitude can easily be obtained astronomically with Marcuse's quadrant, which has been tested in the Wegeners' balloon voyages.

As it appears from the above that airships similar to mine will soon be available for flights of 3,000 miles, the question arises, of what use will they be? To the sportsman a flight across the Atlantic, taking advantage of the trade winds, will not appear too hazardous. Other persons will properly demand an assurance of safety equal to that of an ocean liner. The safety and certainty of the voyage depend upon the force, frequency and duration of opposing winds. A careful study of wind charts has convinced me that —in central Europe at least—a head wind blowing for 48 hours with an average velocity of 6 meters (19.7 feet) per second represents the greatest obstacle to be overcome. As my airship has a relative speed of 11 meters (36.1 feet) per second it would travel against such a wind at the rate of 5 meters (16.4 feet) per second or 18 kilometers (11.2 miles) per hour. It would travel about 850 kilometers (528 miles) in 48 hours, or 1,700 kilometers (1,056 miles) in four days, and still have fuel enough for another day's journey. Hence, in the most unfavorable conditions, it could go 1,000 miles, or 500 miles and back.

If additional persons, extensive apparatus, mails, etc., are carried the quantity of fuel and, consequently, the length of the flight, must be decreased.

Airships with a radius of action of 800 kilometers (500 miles) would be very useful as movable wireless telegraph stations. In war, airships would be valuable as spies in constant wireless connection with headquarters, and possibly as armed cruisers and torpedo boats.

But the most important characteristic of the rigid system of construction is its capacity for development. It requires great dimensions and, as with the ocean steamer, speed, safety and relative economy in first cost and operating expenses increase with its size. An airship only slightly smaller than mine would be useless and an increase of 1 meter (3.3 feet) in diameter with a corresponding increase in length would give an additional buoyancy of 3,000 kilogrammes (6,600 pounds). Such an airship could carry fifty passengers for short trips. It could reach the north pole by easy stages, establish communication between East and West Africa and carry food, water and ammunition to our troops, or rise above the clouds for the observation of a solar eclipse.

THE ELECTROTHERMAL METALLURGY OF IRON.*

By MAJOR E. STASSANO

IT is well known that in ordinary furnaces only a small part of the calorific power of the combustible materials used for heating is utilized. Moreover, the quantity of heat really used varies with the construction of the furnace and the mode of heating. On the average, the thermal efficiency of industrial fuel is only 2 to 3 per cent for a forge fire; 5 to 10 per cent for apparatus in which the heating is produced through walls of refractory material, as in crucibles; from 10 to 20 per cent in furnaces with hearths and in small blast furnaces; finally, an efficiency of 30 to 50 per cent, and even 70 per cent, is obtained in cupolas and large blast furnaces.

The very small thermal efficiency obtained in industrial furnaces is due in a great part to the fact that the necessary element for combustion, viz., the oxygen of the air, being so much diluted by the inert gas, nitrogen, which, during the combustion, absorbs a great deal of heat, lowering the temperature, and necessitating large dimensions for the combustion chamber. Apart from this, a great deal of heat is lost by radiation from the walls, and also by convection. It is, then, readily understood why a high efficiency can be obtained by the use of electric energy for the production of the heat, for the reason that this source of heat is not due to combustion and that the most important causes of loss inherent in the use of a combustible can be avoided.

In taking 20 per cent as the mean thermal efficiency of industrial fuels used for heating metallurgical furnaces, and in putting the thermal efficiency of electric heating at only 50 per cent, it is easy to determine the limits within which the substitution of electric heating for heating by combustion may be realized industrially, and with what resulting economy. The mean calorific power of industrial fuels is 6,500 calories,† while the transformation of 1 E.H.P. hour into thermal energy produces 635 large calories. Taking into account the efficiencies already mentioned, it follows that

$$\frac{6{,}500.20}{100} \div \frac{635.50}{100} = 4.22$$

E.H.P. hours, transformed into thermal energy, produce the same thermal work as that obtainable by burning 1 kilogramme of combustible in an industrial furnace.

The greater number of hydro-electric generating stations produce an electrical horse-power year at a price not exceeding $8.* Under these conditions, if one can utilize 50 per cent of the heat produced in the transformation of electric energy into thermal energy, an electric furnace worked from a generating station which makes use of large water power can work under the same economical conditions as are possible by the use of coal costing 21 fr. ($4.20) per ton.

It may be remembered that in the preceding calculations the thermal efficiency of combustibles in an industrial furnace has been given a higher value than is obtainable in practice. The supposition has also been made that in new electric furnaces only 50 per cent of the heat produced would be utilized, and the cost per electrical horse-power hour has been arrived at by considering only 8,000 hours' running per annum, whereas in reality a hydro-electric installation is used during 8,760 hours per annum, i.e., without interruption.† Further, it must be remembered that in many metallurgical operations it is indispensable that certain special combustibles should be employed, such as coke, which, on account of its manufacture, costs more than natural coal. It must also not be forgotten that the price of coal tends rather to rise than to fall. Under these conditions it will be readily understood that the employment of electric furnaces is a matter of importance in localities where hydro-electric power can be utilized to carry out some of the reactions under economical conditions identical with those which would allow of the use of coal costing more than 21 fr. ($4.20) per ton.

The preceding very approximate calculations do not allow the importance of the problem to be realized exactly, because there is another reason not less important which increases the expense when combustibles are used, and which somewhat militates in favor of electrothermal processes. In metallurgy generally the coal does not serve merely, directly or indirectly, as the reducing agent, but also as the source of heat. It is for this reason, notably in the metallurgy of iron, that when the ore is in contact with the combustible during reduction, it is not possible to determine exactly the quantity of coal absolutely necessary to effect the reduction of the ore and that which is necessary for the production of the required temperature. It follows, therefore, that it is necessary to employ an excess of combustible, an excess which is partly absorbed by the metal, according as the ore is reduced. Under these circumstances, the product obtained after the first operation of reduction of the ore is far from containing the only metal which one wishes to extract. The product is a carbide of the metal, more or less rich in carbon, containing in addition numerous impurities and other metals and metalloids arising from the total or partial reduction of the different compounds found in the ore that is used. This result, which cannot be avoided in the different processes at present used in the reduction of ores by coal, necessitates the first product being submitted to a number of successive refining operations, so as to obtain the metal finally in the required degree of purity. Further, during the operation of reduction, certain impurities contained in the industrial combustibles, and even in the air which is necessary to maintain the combustion, mix with the metal, modifying its composition and give rise to parasitic actions which are generally harmful from the point of view of the success and economy of the succeeding operations.

The electrothermal process depends on a source of heat necessitating neither combustible nor atmosphere to maintain combustion, and its use does not bring with it any of the inconveniences which have just been mentioned. Nor is this all. It is known that the thermal efficiency of a given metallurgical operation is the higher the greater the difference of temperature between the source of heat and the material to be heated. Similarly, the more the surrounding atmosphere is at a high temperature the more active are the chemical reactions which are produced.

Finally, it may be added that the electric energy used for working electric furnaces being generally produced by hydro-electric power, in order that the apparatus should work under the best conditions, it should be installed for continuous working and always fully charged. It is evident that in realizing these conditions fairly completely, the advantages presented by electrothermal methods will be considerably increased. The new processes will permit the metallurgical industry to be installed not only in localities deprived of natural fuels and possessing important water power, but will also admit of certain special applications, even where the fuel can be obtained at low prices, and where it would seem at first sight that practical application cannot be realized.

To sum up, it can be shown that, in order to utilize the heat produced by the transformation of electric energy into thermal energy under industrial conditions, chiefly in metallurgy and particularly in the metallurgy of iron, it is sufficient that the apparatus employed should fulfill the following principal conditions:

1. That the inclosure in which the transformation of electric energy into heat is carried out, and also the metallurgical operations necessitating this heat should be protected from the direct action of the atmospheric air and constructed of materials absolutely inert from the chemical point of view.

2. That the heat developed by the transformation should be produced at as high a temperature as possible.

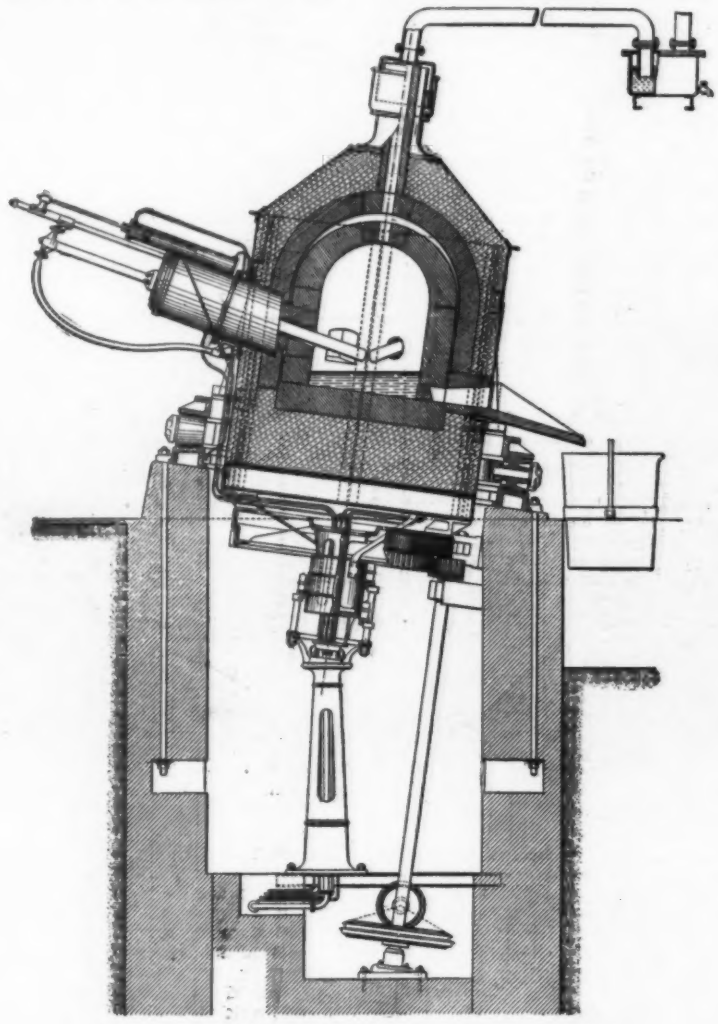


FIG. 1.—VERTICAL SECTION OF THE STASSANO ROTATING FURNACE.

* Paper read at the Sixth Congress of Applied Chemistry at Rome, May 1, 1906 (translated).

† Theoretically, the calorific power of fuels has a greater value than 6,500 calories, but if humidity, which is always rather considerable, is taken into account, as well as ash and other impurities, we find in practice that the calorific power is not above the value indicated.

* At Terni, the retail price per electrical horse-power-year is only 27 fr.

† The Commission sent to Europe by the Canadian Government to study electrometallurgical installations admits in its report the utilization of 8,760 hours per annum.

3. That the materials under treatment should not come in direct contact with bodies susceptible of modifying their composition in a harmful manner.

4. Finally, that the apparatus in which the different metallurgical operations are carried out under the action of the heat produced by electrical energy, as well as the processes for obtaining the desired products, should be constructed and worked in such a manner as to obtain continuous working with a full charge.

It is upon these principles that I relied in studying the problem before me. In a memoir published in the Rivista di Artiglieria e Genio in 1902 I gave a detailed account of the researches and experiments made to determine the definite type of furnace which it was desirable to employ. Referring those who wish for greater details to this memoir, I will confine myself to giving a short description of two types of furnace which enabled me to solve the different problems presented by electrometallurgy in general and more particularly by the electrothermal metallurgy of iron.

As seen in Figs. 1 and 2, the rotating furnace consists of a metallic casing in the form of a cylinder, the upper part of which terminates in a cone. This casing is lined internally with refractory material. The fusion chamber, situated within this lining, is cylindrical in form and is closed by a spherical top. Openings of suitable dimensions are provided in the walls of the furnace to allow of the introduction of the electrodes, which have to penetrate into the interior of the fusion chamber in such a way that their extremities are capable of coming into contact at the center of the chamber, thus permitting the current to pass from one electrode to another with the production of a voltaic arc above the hearth of the furnace and at a suitable distance from it. At each of the openings provided in the walls for the electrodes is a double metallic cylinder furnished on the outside with rods for supporting and guiding the carbon electrode. By means of a suitable sleeve, each electrode is connected to a metallic rod, which, through a flexible cable, makes connection between the electrode and the terminal for current, which is fixed to the lower part of the metallic casing.

The metal cylinder serving as the electrode carrier is made double so that water can circulate through it for the purpose of cooling the interior, thus keeping the metal part of the electrode carrier at a relatively low temperature. At the upper part of the cylinders inclosing the electrodes is a hydraulic cylinder containing a piston and rod, the latter being in a plane containing the axis of the cylinder and connected to the rod of the carbon carrier. It will be seen that by forcing water under pressure to one side or other of the piston this can be moved, and will carry the electrode with it.

The whole furnace, which has just been described, rests on a metallic seat by means of a sort of collar solidly fixed to the metal casing, and this is provided with truncated rollers which rest upon, and can travel freely on, a circular path of cast iron whose surface is in the form of a truncated cone having a very large angle. This circular path is not placed horizontally; it is fixed on a block of masonry in an inclined position so that the axis of the furnace is inclined with respect to the vertical. To the lower part of the metallic casing of the furnace is fixed a solid toothed wheel which engages with a pinion on a shaft that is actuated by means of bevel gear. In this way a rotatory movement can be given to the furnace as a whole about its axis. In the center of the toothed wheel, placed below the body of the furnace, are fixed rings of insulated copper, to which are attached, by means of bars of copper, flexible cables running to the electrode carriers. A series of brushes mounted on a metallic support, which is placed in the center of the cavity below the furnace, bear on the copper rings and are connected to conductors from the generator. In this way a permanent connection is effected between the generator and the electrodes, whether the furnace is at rest or is being rotated. On the upper part of the support for the brushes is fixed a water connection, from which water under pressure is obtained for working the hydraulic cylinders that regulate the electrodes, and also for giving supply to the cooling cylinders, and this water supply is established in such a way as to insure the circulation being equally good when the furnace is in motion or at rest.

In addition to the openings provided in the walls of the furnace for the electrodes, there is one in prolongation of the hearth for removing the products of the operation, one for charging the furnace, and one on top of the furnace in the center of the crown to allow the volatile products, which are given off as these actions take place in the fusion chamber, to escape. This last opening is continued in the form of a pipe arranged in the axis of the furnace. The upper end of this pipe leads by means of a sand purifier and a metallic tube into a washer where the volatile products, after passing through the water, find their way to the atmosphere, or are collected, if they are of such a nature that they can be used. Owing to this arrangement the atmospheric air cannot circulate freely into the fusion chamber, for as soon as the charging door of the furnace is shut the gases are under a pressure greater than that of the atmosphere, and consequently no air can enter. Apart from that, when the door is open for charging, no current of air can pass, because the upper opening is closed by the water contained in the washer.

It is evident that a furnace constructed in this way completely fulfills within practical limitations all the conditions which have been indicated for obtaining the best working as far as metallurgical operations are concerned, because:

1. In the fusion chamber there is always a perfectly neutral atmosphere from the chemical point of view.

2. In the transformation of electric energy to thermal energy by the electric arc the highest temperature which is practically possible is obtained.

3. The materials to be treated do not come in contact with the electrodes, and consequently their composition cannot be modified by the absorption of foreign bodies.

4. Lastly, a continual stirring up of the fused material is obtained in this furnace in a certain and practical manner by the rotary movement which is given to it, by which regular chemical reactions are much facilitated, such reactions being rendered more active and more rapid by the very high temperature which is maintained in the fusion chamber, thus allowing a full charge to be maintained, and a maximum output.

It should be mentioned that the electric furnace, fitted up under the special conditions which have been described, has also the advantage of utilizing the high temperature which is obtained therein without it being necessary to reheat the materials under treatment. In fact, considering this furnace in its most simple form, we see that it consists of an inclosure in the center of which is a source of heat which is not due to combustion, and which gives rise to a very high temperature. Under these conditions it can be understood that the temperature of the furnace tends to become gradually higher and higher until it approximates that of the source of heat by which the maximum is limited. On account of the radiation of the walls, the temperature obtained in the fusion chamber is in the neighborhood of the maximum, but it never becomes equal to it. Consequently, by proportioning the capacity of the fusion chamber in accordance with the quantity of heat which one desires to utilize, and by suitably regulating the charge so as to obtain the necessary heat in the furnace, it is possible to maintain a suitable temperature for good working without it being necessary to reheat the charge.

In the practical operations of metallurgy it is not always necessary to have recourse to the stirring of the mass to render the reactions more active. In that

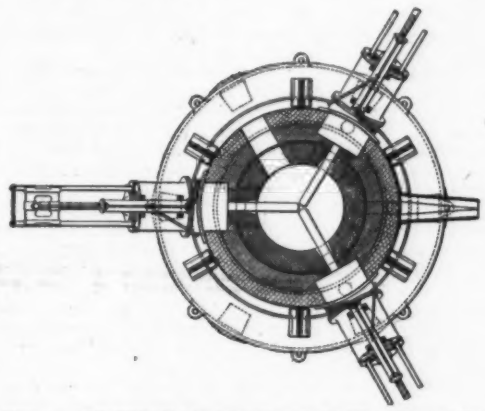


FIG. 2.—SECTIONAL PLAN OF THE STASSANO ROTATING FURNACE.

case the furnace, though constructed on the principles already given, can be very greatly simplified by being fixed.

In this model of furnace the hearth is rectangular in form; the doors for the introduction of a charge are placed on the two smaller sides of the rectangle, while on the longer sides are the tap hole on one side and the opening for the removal of slag on the other. The distribution of heat is rendered uniform throughout the fusion chamber by increasing the points of radiation.

This fixed type of furnace is convenient more particularly for carrying out a reduction previous to refining. The use of this furnace has the advantage of rendering this operation more easy and more economical. This can be verified practically, for example, in the treatment of copper minerals, where it is necessary to maintain the mass in fusion for a long time so as to allow the metallic particles in the mass to separate themselves from the slag through difference of density. In this case the fixed form of furnace allows the required object to be attained, since the molten matter, being in the upper part of the chamber where the temperature is the highest, can remain as a top layer for a considerable time and thus render it possible to have a complete separation between the slag and the useful material, which in this case is the unrefined metal.

It is evident that with furnaces of this kind, suitably modified according to the special requirements of the different metallurgical operations, it is possible to carry them out under much more advantageous conditions than with furnaces in which heating is produced by the combustion of coal.

At the beginning of the present communication I stated that the thermal efficiency of fuels is very variable and very low in industrial furnaces, except in the case of large blast furnaces where the efficiency rises to about 70 per cent. But upon going into the question more closely it is easily seen that this maximum efficiency is only apparent. In reality account must be taken of the fact that in the blast furnace not only is the production of iron ore carried out, but also that of silicon, oxide of manganese, and other substances contained in the mineral. In addition, the different substances become alloyed with the iron, and, far from improving its quality, cause it to lose the malleability and ductility which are characteristic of this metal, thus rendering it necessary to submit the cast iron obtained to long and costly operations of refining in order that iron of a suitable quality of malleability may be obtained. This fact explains why the thermal efficiency of the blast furnace is more apparent than real, since one part of the heat thus utilized serves only to accomplish a veritable task of Sisyphus.

It is well known that the pig, such as is obtained from blast furnaces, is capable of many useful applications, as is shown by the large extent to which it is used in castings in the industry, but if the blast furnace could produce malleable iron directly the numerous articles which are now made of cast iron on account of economy would certainly be made of malleable iron or of cast steel.

Since all the other types of furnace used in the metallurgical industry in general, and more particularly the metallurgy of iron, have an efficiency much inferior to that of the blast furnace, for generally it is not much greater than 20 per cent, we may, for the reasons already given, and without fear of contradiction, attribute to the electrothermal furnace an efficiency equal or superior to 50 per cent of the heat supplied to it by the transformation of electric energy into thermal energy. The new processes founded on the use of this furnace could lead to the establishment of the great metallurgical industry in places where natural fuels are not found, but where there is abundant water power, subject to the condition that the retail price per electrical horse-power year should not be greater than 40 fr. Electrothermal furnaces can, in addition, be used to advantage for certain special operations where such water power is not available, but where natural fuel is abundant, or in places where other cheap fuel, such as blast furnace gases, is available.

Having made these observations, I will now examine the results obtained, so as to see to what extent the theoretical deductions on which I base my experiments have been confirmed in practice. If we knew exactly the quantity of heat necessary to produce the fusion of unit weight of the metals in question to raise them to a certain temperature, as well as the amount of heat required by the different kinds of slag obtained in the course of the operations, and, in addition, we could take into account the heat of formation of the different solid and gaseous compounds formed, it would be easy to determine exactly the thermal efficiency of the new furnaces in which the quantity of energy consumed can be measured very approximately and at any moment. Unfortunately, the information which we possess at the present time as to specific heats of different bodies at high temperatures, and as to latent heats of fusion of metals, and of the slags which are formed during the metallurgical operations, is very imperfect or entirely wanting. It is to be hoped that those who cultivate pure science, and who are interested in the needs of practice, will increase the delicate methods of research which every day reveal to us new secrets of Nature, so that we may arrive at the precise data which industrial processes require for progress. At the present time we must be content with determining the efficiency of the furnaces in accordance with the insufficient data available.

In making use of the results of the calorimetric measurements found in the tables of Lunge, supplemented by Jüptner v. Jörnstorff (Die Untersuchung von Feureungs Anlagen), and which give the quantity of heat necessary to raise the temperature of 1 kilogramme of iron to 1,200 deg., it is possible to determine approximately, by continuing the curve that can be easily constructed, according to the data in the table, the quantity of heat necessary to raise the iron to the temperature of fusion and even beyond. Further, according to information furnished by Gruner, Lebedour, and other metallurgists, the heat necessary for the fusion of slags can be determined.

According to data thus obtained, we may admit that 510 calories are necessary to fuse 1 kilogramme of iron and to raise it to a temperature of 1,900 deg., this temperature being that at which, in general, the cast is made, so that the metal may be very fluid. As to the slags, we must allow 600 calories for the fusion and for raising them to the same temperature when basic.

At the preceding Congress of Applied Chemistry, held in Berlin in 1903, Dr. Hans Goldschmidt presented a report in which he gave an account of experiments at which he was present in 1901 at Darfo, in the rôle of a delegate of the Imperial German Patent Office, so as to determine if my type of furnace would permit of malleable iron being obtained directly from the mineral in one operation. In treating a mineral having the following composition:

	Per cent.		Per cent.
Fe_2O_3	93.020	P	0.056
MnO	0.169	CaO. MgO	0.500
SiO_2	3.790	H_2O	1.720
S	0.058		

he found that iron having the following composition was obtainable by a single operation:

	Per cent.		Per cent.
Fe	99.764	S	0.059
Mn	0.092	P	0.009
Si	traces	C	0.090

—and that in order to carry out this reduction the electric energy required amounted to about 5 horse-power hours per kilogramme of metal produced, which is equivalent to an efficiency of about 60 per cent of the electric energy used.

After these trials at Darfo, I installed a rotating furnace on my system in the artillery works at Turin for the Minister of War, suitable for the preparation of steel to be used in the manufacture of artillery projectiles, the material employed being iron and steel

turnings and scrap iron from the different factories of the Minister of War. From the certificates given by the War Office, referring to thirty-eight successive operations of refining cast iron and scrap carried out in ordinary working with my furnace between May 15 and 27, 1905, and the results of which were given in the Giornale del Forno, published by the Administration, it follows:

1. That the furnace produced in ordinary working 2,500 kilogrammes of steel per day in refining pig iron and smelting scrap, with a loss not exceeding 20 per cent, although the charge included 75 per cent of turnings.

2. That a charge of 600 kilogrammes included at least 150 kilogrammes of pig iron, for the refining of which 29 kilogrammes of iron ore and 6 kilogrammes of lime are required.

3. That each operation requires the expenditure of 850 kilowatt hours of electric energy.

Since the amount of electric energy required was measured on the primary circuit of the transformer supplying the furnace, the amount really required is only equal to about 92 per cent of the 850 kilowatt hours mentioned, i. e., 752 kilowatt hours, if account is taken of the losses in the transformer and in the secondary connections.

From the results obtained in the trials just mentioned, and according to data already given for the calculation of the heat necessary to produce fusion, and for raising a kilogramme of pig and a kilogramme of slag to a temperature of about 1,900 deg., it is possible to arrive at the thermal efficiency of the new type of furnace.

We have, for melting 600 kilogrammes of iron and raising it to a temperature of 1,900 deg., 600 × 510 calories	306,000
For melting about 10 kilogrammes of basic slag, 10 × 600 calories	6,000
For reducing the oxide of iron contained in the 29 kilogrammes of ore added to the charge, the composition being given,* $\frac{29 \times 312}{160} \times 192 + \frac{29 \times 603}{232} \times 279$ calories	28,344
	340,344

Since the amount of energy required by the furnace for each operation was 772 kilowatt hours, we have,

$$\frac{772{,}000}{735} 635.3 = 667{,}256 \text{ calories,}$$

and the thermal efficiency of the furnace is consequently

$$\frac{340{,}344 \times 100}{667{,}256} = 51.01 \text{ per cent.}$$

This result, which is in apparent contradiction to that given by Dr. Goldschmidt, according to experiments carried out at Darfo, is, nevertheless, identical, as we shall see. The furnace installed at Darfo, which required about 100 kilowatts, was operated by means of single-phase alternating currents, and consequently was provided with only two electrodes. In the artillery works at Turin the furnace is supplied from a three-phase network, and therefore requires the use of three electrodes, and consequently of one additional cooling cylinder, which naturally causes the loss of a considerable amount of heat, thus reducing the efficiency of the furnace.

Some figures will enable me to prove the exactness of this fact. According to numerous daily measurements carried out during the running of the furnace, it has been found that three cooling cylinders require the supply of 40 cubic meters of water per twenty-four hours. In leaving the cylinders the water is found to have a rise of temperature of about 15 deg. Under these conditions the thermal losses due to the working of the cooling cylinders represent energy equivalent to

$$\frac{40{,}000 \times 15}{635.3} = 904 \text{ H.P. hours}$$

in twenty-four hours. Since the furnace during this period requires about 200 horse-power during twenty-two hours, and since during the operation of charging and casting the current is interrupted, the thermal losses due to the cooling cylinders are equal to

$$\frac{904 \times 100}{200 \times 22} = 20.5 \text{ per cent, about.}$$

If, on the contrary, the furnace were fed with single-phase current, this loss would be reduced by about 7 per cent, and consequently the same efficiency would be obtained as that given for the furnace at Darfo.

It is evident that in increasing the capacity of furnaces, this cause of loss would rapidly diminish because the quantity of water circulating in the cooling cylinders would be constant, the quantity of energy passing by each electrode would increase, and consequently the loss would be less.

In fact, in furnaces having a capacity of 1,000 horse-power, provided with six electrodes, the thermal losses due to cooling would be, according to figures already found, 904 × 2, since there are six electrodes instead of three. On the other hand, the furnace would require, during twenty-four hours, 22 × 1,000 horse-power hours, whence the percentage of loss would be

$$\frac{904 \times 2 \times 100}{22 \times 1{,}000} = 8.2 \text{ per cent.}$$

It is permissible to conclude from the experiments at which Dr. Goldschmidt was present, and from those carried out in the artillery works, that it is possible in the case of my system, which is worked under the best possible conditions for utilizing electrical energy in metallurgy:

1. To obtain a thermal efficiency above 50 per cent as regards the electric energy supplied, even in the case of small furnaces, where naturally the losses are great.

2. To obtain direct from the ore by a simple operation, malleable iron, as well as steel, of a definite composition by employing a suitable mixture of the pig to be refined, and of scrap.

3. By carrying out the operations out of contact with the air, the maximum efficiency is obtained as regards the materials that are used.

It is therefore evident that analogous results will be obtained in the treatment of other minerals and in the refining of metals other than iron.

In order to complete the account which I have given it would be necessary to mention the processes which, after my experiments, were brought out by other inventors. For reasons which are easily understood I will leave this part of the subject on one side, and I do so the more willingly since the detailed report issued by the commission sent by the Canadian government to study the electrothermal installations in applied metallurgy existing at the present time in Europe, is just completed.

On the other hand, the information which I have just given and the certificates which have been given to me by the War Office as a consequence of the satisfactory working of the furnace which I installed, are sufficient for the value of the process to be determined. At the time when the Canadian commission passed through Turin, the members were not able to see the furnace at work owing to its incomplete state through the refractory material not having been supplied.

Although I have no intention of discussing either the details or the numerous data or deductions found in the report of the commission, I must nevertheless refer to two points in the conclusion arrived at by the commission after they had carefully looked into and commented on the results of trials carried out for the commission at the different works visited.

I am compelled the more to raise these two points because they are in complete disagreement with the logical and natural conclusions drawn from the precise facts which I have just put forward in the present memoir, and which were admitted by Dr. Goldschmidt and by the War Office during the trials at Darfo with the ordinary furnace which I installed for the purpose.

In the second paragraph of the conclusions drawn up by the Canadian commission, it is stated:

"Under present conditions the electric furnace cannot compete from the economical point of view with the Siemens and Bessemer processes as regards the manufacture of industrial steel. Its industrial application is limited to the manufacture of steels of superior quality required in certain special applications."

This assertion does not appear to me to be exact, and the figures which I have given, deducted from perfectly ascertained facts, enable me to prove it.

Mr. Harbord, the metallurgist, who was one of the members of the Canadian commission, recognizes himself, in a special report, that, as regards handling and the manipulation of the furnace, the expense in the production of iron and steel by means of the electric furnace for refining and smelting up scrap are the same as those occurring in the use of the Martin furnace. Consequently, if there is a difference between the expenses of manufacture with the electric furnace as compared with the expenses entailed by the use of the Martin furnace, this difference can only come about in the electric energy required as compared with the consumption of fuel, and by the extent of utilizing initial materials, in which there can be a difference in the two systems of furnace.

It is easy to determine this by making a comparison between a Martin furnace of an average capacity, capable of producing 10 to 12 tons per operation, and an electric furnace of 1,000 horse-power, which is an average power for this kind of furnace.

It will be admitted that in the case of the Martin furnace the losses of initial material are only about 10 per cent, which is certainly not large, and that in the case of the electric furnace these losses are not more than 2 per cent, as determined in the furnace used at Turin. Let us suppose in addition that, in an electric furnace of 1,000 horse-power, the consumption of electric energy is proportional to the figure found at Turin, where the furnace was only of 200 horse-power. By so doing it will be noticed that I place the electric furnace at a disadvantage.

Under these conditions the operating expenses, for fusing a ton of material in the electric furnace, may be estimated at $2.07 as follows:

1,770 kilowatt hours at 0.005 fr. =	$1.77
5 kilogrammes of electrodes at 0.30 fr. =	.30
	$2.07

In the case of the Martin furnace, account must be taken of the cost of the coal necessary to produce a ton of the product, and that of 80 kilogrammes of initial materials, which, as has already been said, are lost. Consequently, if from the $2.07 representing the cost of fusion in the electric furnace is deducted the value of 80 kilogrammes of initial materials at 40 cents per 100 kilogrammes, one has to take account of the price of the fuel necessary to carry out the fusion of one ton of steel in the Martin furnace when comparing the cost of manufacture by the two processes.

In the electric furnace, on account of the loss of initial materials in the Martin furnace, the cost is reduced to $2.07 — $1.12 = 95 cents.

In the case of the Martin furnace of the capacity mentioned, we must allow a consumption of fuel not less than 400 kilogrammes per ton of steel, and in order to obtain a good result it is necessary to employ coal costing at least $2.32 per ton, a price which certainly is not high, even in localities where coal is abundant. It therefore follows that the cost of fuel is 93 cents. In the Bessemer process results are obtained analogous to those of the Martin process, more particularly if account is taken of the fact that with the electric furnace cheap materials may initially be employed, notwithstanding which a good result is obtained, whereas in the Bessemer process it is absolutely necessary to employ cast iron of the best quality, and on which there is a loss of 10 to 25 per cent.

The second conclusion of the commission with which I do not agree is that referring to the manufacture of pig in the electric furnace. In fact, admitting that the essential advantage presented by electrothermal processes, viz., that of allowing malleable iron to be obtained directly by a single operation, as has been proved by experiments carried out and carefully controlled, all the conclusions of the commission on that point are invalid. We must not lose sight of the fact that the production of pig is a necessity imposed by the means of manufacture, and that the necessity for this intermediate product would disappear with the employment of the electric furnace.

In conclusion, it seems possible to assert that if the electrothermal processes have not yet received the great development which might be expected, this is not on account of imperfections or difficulties, but merely on account of opposition, such as is always met by new inventions, precisely on account of their novelty, which raises opposition, or even on account of the natural hostility of industries which, using old methods, consider, rightly or wrongly, that a new discovery would be harmful to them.

The history of progress is full of examples of this kind, but the experience of life shows us that with tenacity and courage, to which must be added sacrifices, the new ideas, if they are good, finish by triumphing over all obstacles which are placed in their way. But in order to realize the progress and to arrive at the desired aim, it is necessary and even indispensable that the ideas which one wishes to put forward should be clearly stated to avoid all misunderstanding and false interpretation.

For this reason, in bringing my communication to a close, in which I have attempted to give an exact *résumé* of the present position of the important problem of electrothermal metallurgy, I wish to state that this new industry has left the period of experiment behind, and that it can now enter tranquilly and with profit into that of practical application, because:

1. The atmosphere in which the transformation of electric energy into thermal energy takes place is protected from the direct action of the air, and is, consequently, absolutely neutral from the chemical point of view.

2. The heat developed by this transformation allows the highest temperatures to be obtained.

3. The materials treated are not in contact with foreign bodies that are capable of modifying their composition in a disadvantageous way.

4. Finally, the apparatus in which the different metallurgical operations are carried out by means of heat produced by electrical energy, and the processes which take place in obtaining the required products, are constructed and designed to allow of continuous working with a full charge.

* The mineral used had the following composition:

	Per cent.		Per cent.
F_2O_3	31.200	CaO. MgO	traces
Fe_3O_4	60.264	S	0.030
MnO	0.135	P	0.006
SiO_2	6.300	H_2O combined	0.320
Al_2O_3	1.800	Losses	0.096

GREATER ECONOMY NEEDED IN THE PRODUCTION OF COMPRESSED AIR.

IT is the rule, rather than the exception, to find a compressed-air plant fitted with the best of pneumatic tools and appliances, but the most wasteful apparatus for compression. This statement, made upon the authority of Allis-Chalmers Company, of Milwaukee, is sufficiently startling to command attention, as is also the fact that for such a condition inventors and designers of apparatus utilizing compressed air are to a certain extent held responsible; "for while they have been actively engaged in improving efficiencies and widening the field of application, they have apparently considered compressed air only as delivered to their machines, without giving much thought to cost of production and delivery." As the use of compressed air is extended in each individual plant, and increased compressing capacity is required, this indifference should give place to a wide-awake consideration of the economies possible in the cost of production.

To illustrate its meaning, the company mentioned enters into a very full explanation, from which we quote the following:

The work performed by an air compressor is, broadly speaking, that of increasing pressure of the air (or other gas) from a lower to a higher stage by reducing its volume or compressing it into smaller space. Usually in air-compressor practice the lower or initial pressure is the "atmospheric pressure" at point of location of compressor, while the higher or terminal pressure is fixed by the requirements of the particular case, and may be anywhere from 10 to 30 pounds (gage pres-

sure) per square inch as in blowing engine practice, up to 80 to 100 pounds per square inch for rock drills, pneumatic tools, etc., and up to 1,500 to 2,000 pounds per square inch, or even higher, for special purposes. Compressors which work against pressures under 30 pounds gage are usually called blowing engines. Atmospheric pressure (or zero gage pressure) equals 14.7 pounds absolute pressure per square inch at sea level (equivalent to 30-inch barometer) and becomes less as the altitude above sea level increases, the decrease being approximately one-half pound, or one inch in mercury column, for each 1,000 feet increase in altitude. As the work of compression depends upon the initial and terminal absolute pressures (absolute pressure being equivalent to gage pressure plus atmospheric pressure) the altitude at which the compressor is to work is of great importance and should always be taken into consideration.

When air is compressed into a smaller volume, if the temperature remains constant, the pressure increases directly in proportion to the decrease in volume; that is, if the volume is one-half, the pressure will be doubled; if one-third, the pressure will be trebled, and so on for any decrease in volume. There is, however, another and most important factor in the problem which must be considered in all cases except the lowest terminal pressures, viz., the increase in temperature and consequent increase in volume due to the heat developed during compression. When air is compressed, the work done during compression is converted into heat, which must be taken up by the air compressed, the result being very materially to raise its temperature and increase its volume, thus adding largely to the work required to be done. Without going into a theoretical discussion of this factor of the problem, a brief statement of facts will show its great importance.

Saving in Power by Cooling During Compression.—If air at atmospheric pressure and 60 deg. Fah. could be compressed to 100 pounds gage pressure and all the heat due to the work of compression taken away as fast as generated, so that the temperature during compression would remain constant, the mean effective pressure during one stroke of the air piston would be 30.2 pounds. If, on the other extreme, none of the heat due to the work of compression is taken away, the mean effective pressure during the stroke will be 41.6 pounds and the terminal temperature will reach 485 deg. Fah. As the power required for compression is directly proportional to the mean effective pressure, it will be seen that the additional power required in the latter case is 37½ per cent of that in the former. In practice, neither extreme can be reached, for it is impossible to completely cool the air during compression, and, on the other hand, some of the heat of compression will be radiated; but the lower extreme is the ideal, and the nearer it can be approached the more economical the compressor will do its work.

Removing Heat of Compression.—Various plans for taking away the heat during compression, such as injecting a spray of water into the cylinder, circulating cooling water through the piston and around the heads and cylinder barrel, etc., have been tried. The use of the cooling spray, or so-called "wet compression," has long since been abandoned, as has also the plan of circulating water through the piston, for the disadvantages more than offset the possible gains. Cylinder heads and barrels are still water-jacketed, not so much on account of the heat that can be taken from air as to keep the cylinder cool enough for proper lubrication. The most effective means for taking away the heat of compression and reducing the amount of power required consists in dividing the compression into two or more stages, depending upon the terminal pressure desired, and cooling the air as much as possible between stages by means of suitable cooling apparatus; the water-jacketing of the cylinders and heads being retained for the reason above stated. Where the work of compression is done in two or more cylinders, it is customary to so fix the ratio of cylinder volumes as to divide the work equally between the cylinders. By using two-stage compression and cooling the air between the stages to its initial temperature (60 deg. Fah.), without considering the cooling by water-jacketing, it is possible to reduce the mean effective pressure to 35.5 pounds as compared to 41.6 pounds in the case above given, which is equivalent to a saving of 15 per cent. At the same time the terminal temperature will be only 245 deg. Fah. instead of 485 deg. Fah. In practice, the saving may be a little less and the terminal temperature somewhat higher, as the initial temperature in both cylinders will usually be higher than 60 deg. Fah., but, after making all allowances, the figures afford an indisputable argument in favor of two-stage compression for pressures commonly used.

Clearance.—Another important factor in compressor design is the clearance in the compressor cylinders. It is not possible to run a compressor without some space between the piston and cylinder head at the end of the stroke, and in addition to this space there is the volume in the inlet and discharge passages between the valves and cylinder space. It is the aim of all good designers to make this clearance space as small, in proportion to the volume swept through by the piston, as possible; for at the end of the stroke the clearance space is filled with air at the terminal pressure, which must expand back to the initial pressure before the inlet valve is opened. This is particularly important in single-stage compression, as at discharge pressures ordinarily used the expanding of the compressed air in the clearance space back into the cylinder seriously affects the volumetric efficiency of the compressor. If the volume swept through by the piston in one stroke is 1,000 cubic inches and the clearance volume is 20 cubic inches, the compressor has 2 per cent clearance. In this case if the discharge pressure is 75 pounds gage (89.7 pounds absolute) and the initial pressure is atmospheric pressure at sea level (14.7 pounds) the air in the clearance space will expand to six times the clearance volume, or to 120 cubic inches, and, as the clearance volume is only 20 inches, the remaining 100 cubic inches must be in the cylinder; that is, the piston must travel back 10 per cent of the return stroke before opening the inlet valve, and the actual room for the admission of free air is only 1,000 — 100 = 900 cubic inches; or, as commonly stated, the volumetric efficiency of the compressor is only 90 per cent.

MEAN EFFECTIVE PRESSURE AND INDICATED HORSE POWER

required to compress a cubic foot of free air (adiabatically) from atmospheric pressure (14.7 pounds) to various gage pressures. Initial temperature of air in each cylinder taken as 60 deg. F. Jacket cooling not considered.

Gage pressure pounds.	Absolute pressure pounds.	Ratio of Compression.	Single compression.		Two stage compression.		Per cent of power saved by two stage over single compression. (Theoretical.)
			Mean effective pressure. Friction included.	Indicated H. P. per cubic foot free air friction included.	I. H. P. per square inch reduced to low pressure air cylinder friction included.	Indicated H. P. per cubic foot free air friction included.	
5	19.7	1.34	5.12	.022	....	....	....
10	24.7	1.68	9.44	.041	....	....	....
15	29.7	2.02	13.17	.057	....	....	....
20	34.7	2.36	16.44	.071	....	....	....
25	39.7	2 70	19.47	.085	....	..	....
30	44.7	3.04	22.21	.096	....	....	....
35	49.7	3.38	24.72	.108	....	....	....
40	54.7	3.72	27.05	.118	....	....	....
45	59.7	4 06	29.21	.127	....	....	....
50	64.7	4.40	31.31	.136	....	....	....
55	69.7	4.74	33.23	.145	..	....	.
60	74.7	5.08	35.10	.153	....	....	....
65	79.7	5.42	76.91	.161	....	....	....
70	84.7	5.76	38.59	.168	33.71	.147	12.7
75	89.7	6.10	40.25	.175	34.99	.153	13.0
80	91.7	6.44	41.80	.182	36.15	.158	13.5
85	99.7	6.78	43.27	.189	37.32	.163	13.8
90	104.7	7.12	44.71	.195	38.38	.167	14 2
95	109.7	7.46	46 12	.201	39.41	.172	14.5
100	114.7	7.80	47 46	.207	40.48	.178	14.7
110	124.7	8.48	50 09	.218	42.34	.185	15.4
120	134.7	9.16	52.53	.229	44.20	.193	15.9
130	144.7	9.84	54.87	.239	45 83	.200	16.5
140	154.7	10.52	57.08	.249	47.46	.207	16 9
150	164.7	11.20	59.18	.258	48.99	.214	17.2
160	174.7	11.88	....	....	50.39	.219	....
170	184.7	12.56	....	....	51.66	.225	....
180	194.7	13.24	....	....	52.95	.231	....
190	204 7	13.92	....	....	54.22	.236	....
200	214.7	14.60	....	....	55.39	.241	....
250	264.7	18.00	....	....	60.76	.264	....
300	314.7	21.40	....	....	65.20	.283	....
350	364.7	24.81	....	....	69.16	.301	....
400	414.7	28.21	....	....	72.65	.317	....
450	464.7	31.61	....	....	75.81	.329	....
500	514.7	35.01	....	....	78.72	.342	....
550	564.7	38 41	....	....	81.30	.354	....
600	614.7	41.81	....	....	83.75	.364	....

TABLE SHOWING THE RELATIVE VOLUMES OF COMPRESSED AIR AT VARIOUS PRESSURES.

Gage pressure pounds.	Volume of free air corresponding to one cubic foot of air at given pressure.	Corresponding volume of one cubic foot of free air at given pressure.
0	1 00	1.00
1	1.068	.9356
2	1.136	.8802
3	1 204	.8305
4	1 273	.7861
5	1.34	.7462
10	1.68	.5951
15	2 02	.4949
20	2.36	.4236
25	2.7	.3703
30	3 04	.3288
35	3.38	.2957
40	3.72	.2687
45	4 06	.2462
50	4.40	.2272
55	4 74	.2109
60	5.08	.1967
65	5 42	.1844
70	5.762	.1735
75	6 102	.1638
80	6.442	.1552
85	6.782	.1474
90	7.122	.1404
95	7.462	.1340
100	7.800	.1281
110	8 483	.1178
120	9 170	.1090
130	9.843	.1016
140	10.52	.0950
150	11.20	.0892
160	11.88	.0841
170	12.56	.0796
180	13.24	.0755
190	13 92	.0712
200	14.60	.0684

RELATIVE VOLUMETRIC EFFICIENCIES AT VARIOUS ALTITUDES ABOVE SEA LEVEL.

Altitude above sea level, in feet.	Barometer in inches.	Percentage of Volumetric efficiency.	Decreased power required, 80 pounds, single stage per cent.
0	30.00	100	.000
500	29.45	98.5	.015
1,000	28.90	97	.025
1,500	28.35	95.5	.04
2,000	27.78	94	.05
3,000	26.75	91	.07
4,000	25.75	88	.09
5,000	24.78	85	.11
6,000	23.86	82	.13
7,000	22.97	79	.14
8,000	22.10	76	.16
9,000	21.30	73	.17
10,000	20.60	70	.18
11,000	19.75	68	.20
12,000	19.00	65	.21
13,000	18.30	62	.23
14,000	17.60	59	.24
15,000	16.95	57	.25

Capacity.—It is the common practice of compressor builders to call the free-air capacity of their machines the volume theoretically swept through by the piston, without making any deductions; that is, if the area of the piston is 2 square feet and it travels 500 feet per minute, the capacity is called 1,000 cubic feet per minute. It will readily be seen that in the case above cited, if the clearance is 2 per cent the actual capacity is only 900 cubic feet per minute, and if 1,000 cubic feet is wanted the compressor must be speeded up to 555 feet per minute. It may be stated in this connection that in the majority of the compressors in daily use the clearance exceeds 2 per cent and the volumetric efficiency is less than 90 per cent. The clearance also adversely affects the efficiency of the machine, for, in addition to the loss from greater friction on account of the increased speed required for a given actual capacity, the air in the clearance space in expanding to the initial pressure never gives back quite as much power as was used in compressing it. Inasmuch as with any given diameter and travel of piston the clearance space is practically a constant quantity, the longer the stroke the less the percentage of clearance. If a cylinder of 30 inches diameter by 60 inches stroke has 1½ per cent clearance and the stroke is shortened one-half, i. e., to 30 inches, the percentage of clearance will be doubled, or 3 per cent. It is therefore better to get the required capacity by using a small diameter and long stroke rather than larger diameter and shorter stroke, even if the advantages of greater reliability in operation, durability, and lower cost of maintenance and repair arising from slower rotative speed for a given piston travel are not considered. As a matter of fact, these advantages, together with the increased efficiencies, will more than offset the disadvantages arising from higher first cost, increased floor space, and greater expense of installation.

The loss of volumetric efficiency due to clearance is less in two-stage than in single-stage compressors, because for any given capacity the first or low-pressure cylinder of the two-stage machine is practically of the same size and has the same percentage of clearance, while the terminal pressure is much lower; consequently the expansion back into the cylinder volume is much less and the volumetric efficiency higher. This fact affords another strong argument for the use of two-stage compressors.

Initial Heating.—Another factor affecting compressor capacities and efficiencies merits careful consideration. It is the common practice to not only rate the capacity at the full volume swept through by the piston, but to assume that the cylinder is filled at the beginning of the stroke with air at full atmospheric pressure and at no higher temperature than the outside source of supply. A moment's consideration will show that such ideal conditions are impossible of attainment. In the first place, even with an unobstructed inlet passage air will not flow into the cylinder without some difference in pressure to force it in, and when, as in many compressors, the inlet valves are of the spring-weighted poppet type, this difference as to its effect upon capacity and efficiency becomes a serious matter. Then, again, the entering air comes in contact with the cylinder walls and clearance surfaces which have become highly heated from the compression in the preceding stroke, and is thereby heated to a higher temperature than before entering. This not only reduces the volume of free air at the outside temperature which can be handled, but also raises the terminal temperature of compression. The latter effect may become cumulative, for the higher the terminal temperature the more the surfaces become heated, and the higher the entering air is heated, resulting in still higher terminal temperature. In cases where the water-jacketing is inefficient or the water circulation becomes interrupted, this cumulative effect may result in heating the compressor cylinder to a dangerous degree. We recall one instance of a small high-speed single-phase compressor which, while working in a rather dark room against 80 pounds discharge pressure, became so heated as to show a dull red. It is essential to good economy that the air be brought to the compressor and gotten into the cylinder with as little heating as possible. To accomplish this the inlet ports should be short and direct and the air admitted in a solid stream and not cut up into thin sheets. Admitting the air through a hollow piston and piston rod, or straining it through metal guards which are frequently used to prevent poppet inlet valves from getting into the cylinder in case of breakage of valve stems, manifestly results in undue heating and consequent loss. In this matter of initial heating of the air, the two-stage compressor has a marked advantage over the single stage, because the terminal temperatures are much lower, consequently the cylinder walls and clearance surfaces do not become so highly heated and the transfer of heat to the incoming air is much slower.

What has been said above applies to compressors of every type, whether for air or other gases, and no matter how driven.

If honest workmanship is desired honest workers will be necessary for its accomplishment; if quantity of output is expected, skill and enthusiastic devotion to duty must be possessed by the operatives; if improvement in processes and perfection of product are to be hoped for, the workers must have intelligence and be given suitable opportunities for its expression; if the organization as a whole is expected to grow, not only in size but in strength and character, facilities must be offered for the improvement of the individuals and inducements made for taking advan-

tage of them; if untiring aggressiveness against competition is desired, absolute confidence in the enterprise and its product will have to be developed in the organization; and if harmonious co-operation between departments and management is to be effected, a spirit of mutual helpfulness must be imbued in the individuals comprising them respectively.

THE WEED FIELDS.*

By B. S. BOWDISH.

ALMOST every country district has its weed tracts, pests of the agriculturist, but joy of the lover of the artistic and beautiful in nature, and incidentally the home of innumerable forms of animal and vegetable life. In spring and early summer these tracts are the haunts of many birds, as well as of numberless species of insects. Here the vesper, field and grasshopper sparrows and the meadow-lark secrete their nests and rear their young. As the season advances the weed growth becomes dense and rank. On the uplands the goldenrod, purple aster and ironweed deck the fields of early fall in glory, taking the place of the white and Michaelmas daisies and dandelions. In damp places the beautiful cardinal flower blazes forth royally. Even in winter there is beauty in the scene, shrouded in its great white mantle of snow, beneath which the covey of bobwhite burrow out a warm, snug bedchamber for their own use.

At this time the vicinity of the human habitation may take on something of an aspect of desolation, but out in the weed field one cannot so regard it. The flock of redpolls sweeping down to feed on the seeds of the tall weeds rearing their heads above the snow, lend color to the scene, while what could be more charming than the graceful evolutions of a flock of snow-buntings? No wonder they have been called "snowflakes," so like are they to the eddying whirls of wind-driven snow! Then who can wander through the snow-covered weed fields without admiring the dainty patterns that the tiny feet of the mice have traced? The weed fields, like all the rest of the world, are either barren deserts or gardens rich in nature

A Belated Turtle Plodding His Weary Way.

lore and pleasure, according to the character of the visitor. If he knows how to see and appreciate, here is an inexhaustible mine of mysteries awaiting his solution, instructive facts on every hand, ready to contribute to his store of knowledge.

Perhaps the early autumn is the most interesting season to visit the weed fields, and a camera is a most valuable companion. Long after the first frosts have touched the foliage with blushes, the "morning cloak" and milkweed butterflies skim the fields and court the goldenrod and aster. Here and there the larvæ that are to bring forth next year's butterflies and moths are feeding ravenously, storing up the vitality that is to carry them through the pupa period of mummy-like inactivity.

Herein, alone, is a subject full of interest, even to the dabbler in nature-study. There are as many species of larvæ as there are perfect insects, and there are three distinct forms in which they pass the pupa stage of their existence. There are those that make a cocoon of silk which they spin after the manner of the silkworm. This is usually placed among the twigs of the tree or shrub on which the larva or caterpillar has fed. It is composed, often, of two or three thicknesses of the silky material, and is tough and strong. Sometimes the outside is reinforced with two or three leaves. In this cradle the larva undergoes the change to the pupa, and in time (in this form, usually the next summer), the second transformation to the perfect insect. These caterpillars are smooth, nearly or quite devoid of hairs or bristles. They are all briskly ready for mischief.

Then there is another form—hairy caterpillars—which construct the cocoon largely from their own hair, usually under some object on or near the ground. The third form suspend themselves, sometimes head downward, by a few silken threads, sometimes by a small mass of threads from the tail only, sometimes head up, with the same kind of tail support, reinforced by a single band about the waist. In this position they undergo simply a transformation in form, becoming chrysalids. When the proper time comes the back skin splits and the butterfly emerges.

* From American Homes and Gardens, Published by Munn & Co,

The class of caterpillars is also naked, and the complete transformation from caterpillar to butterfly may not occupy more than a few weeks. In these transformations many of the insects die. Some are too weak to effect the transformation; some are attacked by the ichneumon fly, or other parasitical enemy. The ichneumon fly stings the chrysalid or pupa

Where the Meadow Lark Secretes Her Nest.

and deposits an egg, which hatches in the body of the host. The developing larva eats away the substance of the pupa when, gnawing his way through the skin, he emerges a perfect ichneumon fly. Thus the chrysalid of the milkweed butterfly that we find may seem, at a glance, to be all right, but observe the hole in the side. That is where the newly born ichneumon fly came forth. Again, the novice cannot always tell whether the silky cocoons that he finds in winter, hanging to the twigs of the bushes, contain living germs of the cecropia, polyphemus, or prometheus moths, or only black, skeleton-like relics of the caterpillars' forms. Time will tell.

The thought of study or drudgery soon passes out of these pursuits. The observer admires the new and the beautiful as does the visitor to a flower garden. He takes home from his winter ramble the deserted summer home of some bird, speculating on the identity of its original owner, and wondering at the marvelous architecture, or the cocoons of a colony of Cynthia moths from the chokecherry bush, and the next summer watches with delight the marvelous transformation, when from these mummy wrappings slowly emerge the moths, with folded, crumpled wings, soon to unfold and spread their glories to the admiring gaze. Then the pursuit becomes interesting. The investigator takes home some summer's day a caterpillar with some of the weed or tree foliage on which it is feeding. He supplies it with a wire screen cage, earth in the bottom, and a bottle of water to hold the leaves, gathered fresh each day, and with the pleasure of an original discoverer, he watches the little creature's development.

Most insects are short-lived beings. In the mature state very many of them live only long enough to insure the reproduction of their kind. During one period or another of insect existence a few species are beneficial to man, as the bees which furnish honey and fertilize the flowers, and certain predacious insects which prey upon noxious species; and very many are harmful, consuming or destroying various forms of vegetation. To one seeking a harmless, and at the same time instructive "fad," insect collecting within reasonable bounds can be recommended with free conscience, from the humanitarian standpoint, because the life is destroyed but very little before the allotted

The Toadstool to Which Ignorent Belief Once Assigned the Function of a Toad's Seat.

THE WEED FIELDS.

time; from the economic standpoint, because the sum total of the destruction of the insects involved will be beneficial to man.

When the observer of nature goes afield with the camera, there are thousands of beautiful little phenomena that claim his attention, which otherwise might pass unnoticed. The katydid and the grasshopper on the weed and bush stalks, the dainty thistle and milkweed down, whose seeds the trim little goldfinches eagerly harvest, the solemn toad, whose big, twinkling eyes are ever alert for unwary insects; the toadstool, which ignorant belief formerly gave the function of a toad's seat, and which figures so prominently in fairy tales. Just beyond the big clump of purple asters, where the rustic bridge spans the quiet pool, the frogs in guttural tone invite the amateur photographer to essay their portraits. Among the dead leaves on the bank, a belated turtle hustles away to select his winter resort. Spangled with dew, the cart-wheel web of the spider gleams, while in the twigs of the stunted cedar hangs the storm-battered home of the paper wasp. If instead of fall it be spring, unfolding fronds of fern, and innocent-eyed blue violets delight the gaze. At whatsoever season, wander with eyes and ears really open in the weed fields, those tracts despised by man, and manifestations of life, most wonderful and interesting, greet you on every hand. You make the acquaintance of innumerable little neighbors you knew not of before; your world is enlarged, your pleasures multiplied, and you come to feel that you have found a veritable garden of Eden in the weed field. And this is done easily, readily and without real exertion. There is vigor given to a day's outing when there is some definite end attached to it, something real to do, and something interesting to find. The camera yields no greater joy than when put to nature study. Lasting mementoes of one's walks, its work is never toilsome and its pleasures always delightful.

HERALDRY IN RELATION TO THE APPLIED ARTS.*

THE imaginary animals that occur with such conspicuous effect in heraldic design would well repay the expenditure of more time than we can devote to them now. I must, however, be content to mention a few of their characteristics. The unicorn perhaps inter-

The Solemn Toad Whose Big Blinking Eyes Are Ever on the Alert for the Unwary Insect.

ests us most as an important part of the royal insignia. You may remember that two unicorns were the supporters of the royal Scottish arms, and when King James succeeded to the English crown he used one of them as his heraldic supporter, with the lion of England on the other side, as they appear to this day. In so doing, the Tudor dragon, the dragon of Cadwallader, was displaced as a supporter though it still remains a royal badge. The unicorn is of composite character, having the head and body like those of a horse with the legs and cloven hoofs of a stag. A twisted horn issues from the midst of its forehead and its tail is usually that of a lion, in some cases is that of a horse, but it also has a tuft under the chin and others on the legs as a lion has. An instance of the latter form occurs in the supporters to the arms of the Goldsmiths' Company. Another form of unicorn, shaped like a goat, was also described in the "Bestiaries," those early and very meager natural histories which supplied information (of a sort) to the mediæval artist. This suggested the goat-like type of unicorn, with a short tufty tail, that occurs in foreign heraldry, the German and Swiss work for example, and no doubt it was from one of these sources that Pugin took the type when he introduced it into the royal armorials in the windows of the Houses of Parliament.

Next to the unicorn the griffin is most popular, as is shown by the application of its name to a creature which is not a griffin at all, viz., the dragon supporter of the arms of the city of London, at the place in the Strand where Temple Bar formerly marked the dividing line between London and Westminster. Griffins are half eagle and half lion, a lion's body with eagle's wings and head, and with eagle's legs for its forelegs. It must be particularly noticed that the head has large ears, and these form the distinction—a necessary one when a head only occurs—between that of a griffin and that of an eagle. Griffins in pairs form admirable decoration, as is seen in the front of a fifteenth-century coffer in modeled and painted gesso that is in the Victoria and Albert Museum.

* From the Cantor lecture, by George W. Eve, published with illustrations in the Journal of the Society of Arts.

Dragons are imaginary rather than composite creatures, and vary much in character, in many instances having a hard scaliness that is suggestive of the Chinese variety. In other examples a greater sinuosity and a more leathery texture is apparent, recalling the idea of "the loathly worm" of some ancient dragon legend. It was made part of the royal armorials by Henry VII., whose favorite badge it was, and became one of the supporters of his arms after flying, as a badge on a banner, over the fateful field of Bosworth.

The character of the dragon's head has also varied very much, from being comparatively short and spiky, resembling somewhat the demons' heads of the Assyrian sculptures, to having a much longer and more crocodile-like form, and to this there is now a tendency to revert. It is important to note that in English heraldry a dragon has four legs, and that a somewhat similar creature which has but two is called a wyvern, but that it is the latter form which is known to foreign heraldry as a dragon.

The crest is next in importance to the armorial shield and therefore demands a similar attention. Originally it was the badge displayed on the top of the helmet, in which conspicuous position it was even more distinguishable than the arms on the shield. It was at first a purely personal bearing that was confined to such as were actually knights. The knightly rank was very important, and we find Henry III. swearing to observe a covenant "As I am a man, as I am a Christian, as I am a knight," and this importance accounts for the special estimation in which the crest was held, apart from its prominence in the mimic battle and from its position as the apex of the heraldic group. This also accounts for its tardy acquisition of that hereditary quality which made the shield a family matter no less than a personal one.

The first kind of crest-like ornament to appear on the helms, which became so intimately associated with this kind of device, was an artificial derivation from what may be called a natural crest, a plume or panache of feathers. This was probably made of leather or of thin metal in the fan shape that appears on some of the seals. Some interesting crests of shaped leather occur on the Celtic headpieces in some of the painted MSS. as early as the ninth century, but it would be too far-fetched, perhaps, to suggest any special connection between them and the fan crests of four centuries later, for helmets had rarely at any period been without some kind of crest decoration.

Still Another Form of Hairy Caterpillar on Its Feeding Ground.

It has been mentioned that a crest is a badge or device placed on a helm, and it is worth noting that when it is removed from its helm it may be used as a badge again, an adaptation that may be very useful in allusive heraldry in cases where the whole arms may not be suitable to the general design.

Few examples of actual crests survive from those picturesque times, among the most notable being the lion crest that was carried in the funeral procession of Edward the Black Prince, and afterward hung over his tomb in Canterbury Cathedral, where it still is. Another is that of the Spanish hero, James (the Conqueror), King of Aragon, in the royal armory, Madrid; and a third is the dragon's head crest that was formerly in the celebrated Bardini collection, now dispersed. This dragon crest is a very bold and striking example of Florentine work of the late fifteenth century, and is probably the best specimen of a tournament crest that remains. High and sinuous crests seem to have found great favor with the Italian nobility, as is evident in the armorial tablets and panels of the architectural decoration. The Bardini example is about 17 inches high, modeled in leather and painted, and the torse is also represented modeled in the same material.

Unfolding Fronds of Fern.

Prince Edward's crest, which accompanies the shield that we have already examined, must have been a very fine piece of work when its eyes and tongue were in their places, and the tail, perhaps, had a more spirited pose, but even in its present state it is a very interesting example. Shaped in plastic leather finished with gesso (in which suggestions of hair have been modeled), it was afterward gilt and painted. The eyes were probably of glass, or may even have been jewels. Leather, softened by soaking in hot water, was the ordinary material for modeling crests, a core of wood being often employed to give stability to the whole. In other cases crests were modeled over a framework of wicker, and paper and canvas were used, as well as leather, with which to build up the figure, the final surface being nearly always of painted and gilt gesso.

The comparative lightness of the materials of which crests were composed enabled them to be made of imposing size, a fact to be taken full advantage of in representing them, and this has been the custom in all good heraldic work, their heraldic importance and their artistic value at the top of a composition alike tending to exaggerate what was already large, until, in much of the work of the fifteenth and sixteenth centuries, they became enormous.

In depicting crests the sense of stability should always be kept well in mind, for the suggestion of being, as it were, a part of its support, and not of being merely balanced on it, is essential to good heraldic design. Doubtless it was due to such practical necessities that so many of the early crests were demi-animals, animals' heads and other objects which could be secured in their places with least difficulty. At the same time, whatever meaning or symbolism was intended by the complete figure was equally conveyed by its more convenient representative.

Here again practical necessities, and the way in which they were met, resulted in decorative excellence, the lines of the crest being thus brought into pleasant relation with those of the helm and mantling in a very admirable manner. Heads are particularly effective in this way. They were often treated as a sort of cap to the helm, and merged, without a break, into the mantling. Whole animals were usually in the statant position of the crest of Edward the Black Prince and of the royal crest of the present day, the militant rage of the lion in the shield being somewhat curbed in the crest by the necessity for a firm fixture.

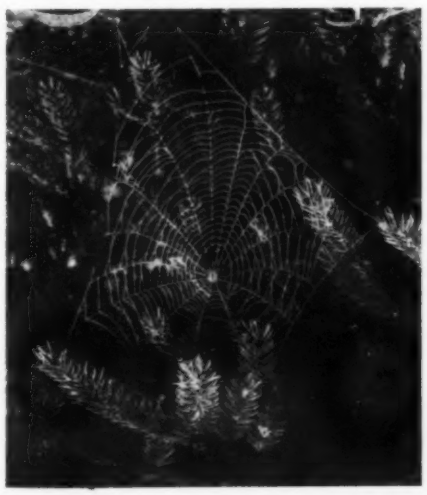
Some Make a Cocoon of Silk.

These were some of the considerations that influenced early heraldic design, and are points that may be usefully kept in mind in interpreting it.

It would seem superfluous to say that animals as crests should face in the same direction as the helm, that is, in the direction of advance, if it were not for the fact that surprising instances exist of lions and other beasts placed across a helm, and even being made to face toward the back of it. The position of a knight's crest looking over his shoulder, or down his back, would have somewhat astonished the heralds at a tournament, and the spectators would have "made remarks," without doubt.

In the general decline of decorative art in the seventeenth century heraldry came off very badly, and the crest especially suffered ill-treatment. This was intensified by the impractical nature of many of the large number of new crests that were devised during the period that began soon after the cessation of the tournaments and continued until modern times; such as objects of all sorts between branches or between pairs of wings that are posed fore and aft on the helmet, one pointing over the wearer's nose and the other down his back; objects placed with much confusion in front of each other; rows of small objects in front of the principal one, and even birds flying and quite detached from support.

In one sense the evolution of a modern crest is exactly the reverse of the ancient method. Then the device was first produced in the round, as an actual crest, and consequently its transition thence, to any form of applied design, gave rise to no trouble of a structural nature. In more modern times crests appear to be devised solely with regard to heraldic difference, and as though they were to be viewed from but one aspect, any possible treatment in the round being generally left completely out of sight, as though newels and finials (carved in wood or stone, or cast in metal) or silverwork (such as the handle of a cup-cover) had never been heard of. One feels a sense of



Spangled with Dew, the Cart-Wheel Web of the Spider Gleams.

From the Mummy-Cradle Slowly Emerges the Moth with Folded, Crumpled Wings.

THE WEED FIELDS.

The crested helm of Pallas Athené comes to mind as a classic instance, with its triple crest ridges adorned with owls and winged horses.

The fan-shaped crests developed into a flat form with a cusped edge, and this was treated as a space on which to repeat the arms (or perhaps a single charge) rather than as a definite bearing in itself.

injury at the very existence of things that almost defy good treatment, and even though it is the duty of an artist to tackle difficulties and beat them, he cannot help resenting their unnecessary aggravation.

The principal difficulties in an ordinary way occur in regard to objects that are between branches or pairs of wings, especially when the last are charged with other objects.

As already said, figures of living things naturally face the front, while other objects are posed in the way in which they can best be seen. Flat objects, such as roundles, roses, portcullises and so forth may be placed across, or fore and aft, as seems best in each case, both sides of the object being assumed to be painted with such details as may be necessary. With regard to crests, it should be remembered that the essential point is always complete legibility, combined with a definite and reasonable relation to the helm and to the rest of the composition.

Fleur-de-lis crests were sometimes made in a very effective way by two of them being made to intersect each other at right angles like a vane, so that the complete form of the object was visible from every point of view.

As an effective support for the crest, the helm next demands attention. Following the same plan as before, we will consider its actual structure, so that, knowing the principle on which it was formed, we may be able to design any number of helms and so be spared the necessity of repeating one form too often, or of finding a new model for every fresh need.

With regard to this and other parts of armor (and much of it occurs in heraldry, from the mailed hand as a crest to the complete suit of a figure supporter) you cannot do better than acquire a good working knowledge of the actual thing, the practical reasons for the form of its parts and the manner of their working. By so doing you will learn to handle the subject with confidence, so that light and shade and the harmonious co-relation of lines may be secured, while the structure appears convincingly right.

At first the helm was short and was worn on and supported by the head over the camail. It was provided with eye-slits or occularia, which were reinforced with an additional plate that was usually in the form of a cross, a feature which may be varied and elaborated at the ends to a very decorative extent. You may be interested to know that the endeavor to lessen the weight without weakening the defensive power caused the back plates to be made thinner than the rest. This is one of the means of detecting forgeries, by the way. By the end of the fourteenth century the efforts to find a more perfect defence had resulted in the various forms of helmet, the small helm lighter and with movable parts that was less fatiguing to wear than the great helm, which from that time forward was reserved for the tournament. The tournament helm for this purpose was much strengthened, was made longer until it rested on the shoulders, and so became a part of the body armor, to which it was firmly fixed back and front by straps and buckles. By this means the head was relieved of the weight, which was transferred to the body, and so the use of large crests as well as strong helms became possible.

Helms were of many shapes, which were, at the same time, but variations of the same general structure. The slope of the crown plate took different angles, the projections of the front plate increased, with consequent variation in the line of the middle ridge, and so forth. This bold strong line is of great importance in the composition of groups, in linking together the crest and the shield. Sometimes the lower edge of the helm spread out into a large gorget, and to it were riveted the various attachments by which it was fastened to the body armor.

The central position of the helm in the heraldic group, a position in which it is, as I have said, of great value, both as a support for the crest and as a link with the shield, has, however, the disadvantage of tending to over-emphasize it, and this must always be taken into account. In painting there will be no difficulty in bringing it into proper keeping, especially when it is remembered that helms were sometimes themselves painted and their rivets gilt.

In certain forms of black and white, such as strong simple line, the perforations and structural lines will be found very useful in supplying decorative detail that will also tend to lower the general tone. The perpendicular join at the side may also be ornamented, of course, in a metal-like way, as by filing into cusps the spaces between the rivets, and the latter may become small bosses. The value of such detail is well shown in most of Dürer's heraldic engravings. He, of course, knew perfectly well what he was about with armor, as may be seen in the death's-head coat-of-arms and in the coat-of-arms with a cock. The helms in these compositions are almost identical with the actual tournament helms that Dürer designed to the order of the Emperor Maximilian. Another point which keeps the due relations of the helm is its forward tilt, which produces a strong tone on the part of the helm that is between the eye-holes and the gorget. This tilt is due to the fact that the highest point of a helm is considerably behind its center, and, therefore, when the helm is fixed on the top of a staff or stake it naturally tilts forward, while at the same time the crest is brought upright. In the tournament helm there are holes in the crown plate, some of which were for fixing the crest and mantling, others being to secure a lining in the helm.

The great helm was that which was usually represented in connection with crests down to the sixteenth century, and is by far the most satisfactory in every way. It was always represented in profile, or nearly so, down to the first half of that century, and it therefore displayed the crest in a very satisfactory manner. With the cessation of the tournaments real touch with early heraldry was soon lost, and the helmet, the lighter and more flexible head-piece, took the place of the helm in contemporary heraldic art. About the same time began the over-elaboration of heraldic rules, and it was arranged that the helmet should signify the rank of its bearer by its pose, and so we got to the present official rule—that an esquire's helmet is in profile with vizor closed and is of steel with gold ornaments; that of a knight is of similar form, but full faced, with vizor open; a peer's helmet is protected with gold bars and is profile; while that of the sovereign is all gold, is barred and full faced. It was also attempted to make the number of bars denote exact rank, but fortunately that effort failed. There is really no necessity for anything of the kind except in the case of a knight. A peer is perfectly distinguishable by his coronet, as the king by his crown. The reversion to the great helm in heraldic art began with Foster's Peerage, and is happily now well established.

Unlike the closed helmet the barred helm, as a crest support, has the sanction of actual use, being derived from the special headpiece which was used in the tourney, as distinct from the joust—the duel with lances, as already indicated.

In the usual group of shield, helm and crest the helm usually faces to the left—that is to say, to its own proper right, the dexter side, but this is not necessarily so if there is any reason for the contrary position, such as its occurrence in a book order, when it might help the general composition of the page to face the arms inward.

In architectural decorations it may be advisable to face all the helmets of a series in one direction in relation to some central point, and they are often so treated in early works. Armorials in a chapel, for instance, often face toward the altar, and in domestic decoration they turn toward the fireplace.

When two or more crests are ranged above a shield they are usually faced inward, toward each other, with great advantage to the composer of the armorial group. If, however, it is desirable to face them all one way, in relation to the composition of a larger design of which they form a part, there is no heraldic objection to interfere with such a course. In other words, you may pose helmets in any way you think fit, except the full-faced position, which may be fairly reserved for those who are entitled to it under the ordinary rule. In German heraldry the charges of the shield are also made to turn the reverse way on occasion, and those on quartered arms are sometimes made to turn toward each other on the same shield. Both methods are, however, contrary to English practice, and should be avoided.

In addition to the tournament helms and their derivatives, many other headpieces were sometimes used to support crests, such as the salade on the medal of René d'Anjou in the fifteenth century; but this instance may be ascribed to the influence of the Classic style, toward which all were looking at the period, rather than to heraldic suitability. Salades came between the helms and the helmets, but are rarely used in heraldic design, most of the existing instances being found in German work.

From the helmet the mantling starts, covering its crown and hanging at its side, in some one of the immense variety of its ornamental forms. Heraldic rules have nothing to do with the form of the mantling, only with its color, and the great freedom of treatment thus made possible is, of course, extremely valuable.

The treatment of mantling as ornamental form should be such as to support and supplement the shield and its bearings, and to assist in linking together the whole composition. Endless variety will be found possible in its design, and also in the way in which its lines may help each other in direction and force. The facility of twisting the main parts and of folding over the edges and ends is extremely useful in correcting balance and adding detail, as well of form as of color; twisting and folding in this way being practically without limit. Such details must, of course, be designed to assist the swing and flow of the whole thing, or else be in obviously intentional opposition in crossing over; otherwise they will be confusing and worrying.

As to the color of mantling, the only point on which heraldic rule has anything to say, the matter is very simple, so far as relates to modern memorials and to English use, viz., that the mantling follows the tinctures (the first color and first metal) of the arms, where of peer or commoner. Thus, if there are but two there can be no question, but if there are more, the first color and the first metal that are mentioned in the blazon govern the mantling.

The mantlings of the king and of the princes of the blood are exceptions, those of the sovereign and of the Prince of Wales being of gold lined with ermine, and those of the other royal princes are also of gold, but their lining or doubling is white.

Formerly peers used mantling of their color lined with ermine, and this is still the Scottish practice. Those who deal with color, especially perhaps the glass painters, will no doubt resent this restriction, but I fear that it cannot be helped. The quality of the color is, however, at their disposal, so that one may paint the mantling in lower tone than the shield in order to emphasize and make brilliant the central motive, or otherwise treat it as in one's discretion may be thought fit. The color side of mantling may be decorated with lines and veinings of gold, as is done with charming effect in embroidery, and in addition powderings of badges may help to give a rich and decorative effect. There are many instances in early stall plates, and there is no heraldic reason against the modern use of this method of obtaining diversity of color and interest.

The mantling being laced to the helm, and the crest fixed in position at the top, a torse of twisted silk was, as you know, placed round it. This is the wreath which has been so hardly treated in modern times, generally as though it were the edge of a shelf on which the crest rested, instead of being, perhaps, a lady's favor.

In present design the colors of the torse follow those of the shield, and consequently of the mantling.

[Concluded from SUPPLEMENT No. 1615, page 25879.]

GAS AS A SOURCE OF POWER.—II.*

GENERATION OF PRODUCER, MOND, AND BLAST FURNACE GASES.

By WILLARD L. CASE.

Perhaps no better idea of the capabilities of the system in this direction can be had than by briefly quoting from a paper by John Langton, read before the American Institute of Mining Engineers in 1903. It refers to the power plant of the Moctezuma Copper Company, Nacozari, Mexico. The power plant consists of eight gas engines, each direct belted to a 65 kilowatt direct-current generator.

"The original intention was to make producer gas and water gas at Nacozari in the usual manner, by alternate blowing and steaming; but in a plant operating only one set of producers, as at Nacozari, the quality of the mixed gas was too variable. The method of gas making was therefore modified by introducing steam pipe connections, affording graduated regulation, to permit the introduction of steam together with the air to the top of the fire; and by this means the excess heat of the fire, caused by the air blowing, was concurrently used to make water gas. But in order to maintain the necessary state of equilibrium requires an adjustment of air and steam rather too fine for easy every-day working, for which reason the method preferred is to admit somewhat less top steam than could be used, in order to allow the fire to increase slowly in temperature; and then, without allowing the temperature to become excessive, to make a short water gas run, which only slightly pulls the fire, and to resume immediately the making of mixed gas from top steam. This also distributes the heat more uniformly throughout the column of fuel, and in a manner shakes it up enough to prevent the formation of holes or masses of clinker. The water gas, made separately by this method and delivered into the water gas holder, is gradually fed from the latter into the main holder which supplies the gas engines, the water gas holder being weighted to give an inch or two greater pressure than that of the main holder. The rate of feed is controlled by a throttle valve, in a pipe connecting the two holders, which the operator manipulates so that the rate of feeding water gas approximately equals the rate of its production. No particular accuracy is required, nor are pains taken to regulate the quantity of water gas made separately. The operator is governed principally by the temperature of the fire, as indicated by its appearance, and by the rise of steam pressure on the boiler. If the fall of the water gas holder necessitates the making of water gas before the fire seems quite hot enough, the throttle valve opening is slightly lessened, and *vice versa*. This is not a point which varies much during the day or even from day to day.

"By this method it has been found quite easy to make gas, such that the variations in its quality, shown by analysis and calorimetric readings, have no observable effect upon the working of the engines or upon their efficiency."

An analysis of the gases made in the producer from anthracite and bituminous coals and wood is here indicated, each analysis being the average of a consecutive six-day test:

	Anthracite Coal.	Bituminous Coal.	Wood.
	Per cent.	Per cent.	Per cent.
CO	21·60	21·32	13·27
H	12·68	13·08	20·97
CH_4	1·86	2·35	2·61
C_nH_n	0·18	0·20	0·28
CO_2	8·10	7·66	15·96
O	0·20	0·04	0·11
N	55·38	55·35	46·80
	100·00	100·00	100·00
Calorific value (B.T.U.)	131·1	133·47	140·22

It is noted that, for more than three years, the gas plant at Nacozari has been furnishing the engines with producer gas made from wood and the entire plant is efficient and satisfactory.

In general, it may be said that whatever the nature of the gas used, an engine of proper design will consume 10,000 to 12,000 B. T. U. per brake horse-power per hour at or near full load. With producer gas of 125 B. T. U. per cubic foot (the average value of anthracite gas) the consumption will approximate 80 cubic feet per brake horse-power hour, and it is evident, from actual demonstration, that a well-equipped gas power plant, operating on producer gas from any of the coals should show a duty of at least 1 pound of coal per indicated horse-power hour.

The stand-by losses of such a plant are very small in a good producer—the consumption of coal during

* Journal of the Society of Chemical Industry.

these periods averages about 3 pounds of coal per hour in plants averaging only 250 horse-power.

MOND GAS.

Mond gas, really a producer gas, is a representative of the ammonia recovery systems.

The fuel used is any description of free burning rough slack; it is claimed for the producer that by the use of an especially long fuel feeding bell, extending well down into same, the green fuel therein undergoes distillation, resulting in the removal of the tar vapors by forcing them down through the hot fuel bed, but this is subject to limitations, for a coal of strongly coking nature is not desired, nor is it suitable for use in this producer.

The advantages of the Mond system are the use of a cheap coal and the recovery of a valuable product—ammonia. Its disadvantages are that when arranged to recover ammonia from the coal a great complexity of costly plant, apparatus, and operation is demanded, that when installed without the recovery system, while producing excellent results, it is on the same basis as other systems which employ only one generator—i. e., bituminous coals are not satisfactorily handled, especially if they be of a strongly coking nature.

The Mond system may be an attractive proposition for just such an installation as they are now making in Great Britain, where a central generating station of 40,000,000 cubic feet daily capacity will distribute this gas to numerous towns and through a district covering 123 square miles. This is one of five contemplated stations of like character to complete the system within this district, but it would seem that so extensive a field were really the province of the by-product coke oven plant, and that the Mond recovery system fitted best that proposition about half way between the coke oven and the ordinary producer gas systems.

The apparatus of the Mond system is briefly noted in the description of the gas-making process, following.

The producer is provided with a water seal, and is so constructed as to allow the ash, which is the only residue, to descend into the water, from which it is easily removed without interfering in any way with the working of the producer.

The process of combustion in the producer is carried out at a comparatively low temperature, with the two-fold object of preventing the formation of clinkers in the producer, and of providing against the destruction of ammonia. This is accomplished by introducing into the producer a blast of hot air and steam. The quantity of steam required when it is desired to recover the ammonia from the gas is equal to 2½ tons per ton of fuel, gasified, but of this about one ton is automatically recovered and used over and over again. In those installations where ammonia recovery is not made the steam required is about one ton per ton of fuel.

After leaving the producer, the gas passes through a regenerator so arranged that part of the heat of the gas and steam entering it is transferred to the blast of air and steam on its way from the air-heating tower to the producer, the gas being consequently cooled to a corresponding temperature.

After leaving the generator the gas is delivered to a mechanical washer, where, by intimate contact with water, the temperature of the gas is further reduced, and all soot and dust are removed from it.

The next step is the recovery of the ammonia contained in the gas, and for that purpose it is passed through an acid tower where the ammonia is completely absorbed by a dilute solution of sulphuric acid. This acid solution circulates through the acid tower again and again until it contains from 36 to 38 per cent of sulphate of ammonia. Continuity of the process is provided by adding from time to time fresh supplies of sulphuric acid and withdrawing corresponding quantities of sulphate liquor, which latter are then evaporated, yielding solid sulphate of ammonia of good salable quality.

After the gas has been washed of its ammonia products, it passes through a final cooling and cleaning water-tower and is then ready for use. As the gas is cooled in this final tower the steam with which it was burdened condenses, and the cleaning water, which entered the tower cold, is delivered hot; and this, after passing through suitable tar separators, is again pumped to the air-heating tower, where it serves to heat the air required for the producer blast.

Into the air-heating tower a blast of air is forced by a blower, and, in its contact with the descending stream of hot water, becomes heated and saturated with vapor; it is thence carried through the regenerator and to the producers as already noted.

The water which was delivered hot to the air-heating tower, after heating the blast, is drawn off sufficiently cold to be returned to the top of the gas cooling tower to repeat the cycle.

This method of continuously employing the water in circulation as the heat carrying agent between the hot gas in one tower and the cold air in another, and the method of recovering from the hot gas, by this continuous cyclic exchange of heat, a large proportion of the steam required for the producer blast, are important features in the economy of this process.

The distinctive feature of the entire process is the economic production of a good engine gas from very cheap coals; the economy of the process being very greatly enhanced by the recovery of ammonia and its conversion to a salable ammonium sulphate.

The Mond system as installed for power plants under 5,000 horse-power does not warrant the installation of the ammonia recovery process.

The following is a typical analysis of Mond gas, being the average of several analyses at plants with and without the recovery system:

	Without Ammonia Recovery.	With Recovery.
	Per cent.	Per cent.
CO	11·0	13·8
H	27·5	24·3
CH_4	2·0	2·0
CO_2	16·5	13·9
$N + H_2O$	43·0	46·0
	100·0	100·0
Total combustible in the gases	40·5	40·1
Calorific value	145·6	144·2

The coal used was slack, with an average analysis in both instances of:

	Per cent
Moisture at 100 deg. C.	8.6
Volatile matter (excluding carbon)	18.29
Total carbon	62.69
Ash	10.42
	100.00

The calorific value of the dry fuel was 12,213 B.T.U. per pound. The average production of gas per ton of fuel consumed, by either process, is about 140,000 cubic feet of gas of a calorific value of 140 B. T. U. The efficiency of the process of fuel conversion does not fall short of 80 per cent.

Tests have demonstrated that this system is capable of producing power in a good engine with a consumption, in the producer, of 1 pound of coal per brake horse-power hour.

It may be interesting to note the stand-by losses of this system:

It is stated that the stand-by losses of a 1,000 horse-power plant are about 225 pounds of fuel per night of 14 hours, and that when standing for eight days, they are at the rate of about 7½ pounds per day. After the week-end stoppage, the time required for starting is only three minutes for such a plant.

It is evident that, for ordinary installations, the worth of the Mond system approximates the average producer plant; and for the large central power station it may exceed same by reducing the cost of power by the value of the ammonia sulphate recovered. It is claimed that in a 20,000 horse-power plant under continuous operation, the production of ammonium sulphate will approximate nearly 3,000 tons per year. The net profits of this, after deducting all costs of production, will approximate $1.75 per gross ton of fuel gasified; this figure was slightly exceeded in the works of Messrs. Brunner, Mond & Co., England, during a 12-month operating period. At the only "Mond" plant in America, where 150 tons of coal are gasified per day, it was found that the value of the by-products recovered, after deducting the cost of labor, repairs, and chemicals required, reduced the cost of coal some 50 cents per ton to the plant.

BLAST FURNACE GAS.

It has been stated by reliable authorities that the total amount of available power lost in the waste of blast furnace gases varies from one and a half to two million horse-power per hour.

The generation of blast furnace gases and the total surplus available for power in any one instance, may be determined thus:

To produce one ton (2,000 pounds) of pig iron requires a furnace charge of:

	Pounds.
Ore	3,400
Coke	2,000
Limestone	1,000

Assuming for these factors a good average quality, we would have an analysis something like this:

Coke.—Good hard coke, 85 per cent fixed carbon.

Limestone, 42 per cent CO_2, containing 115 pounds of carbon per 1,000; and for the pig iron producing an analysis approximating—

	Per cent.
Iron	93.50
Carbon	3.75
Silicon	1.50
Manganese	0.80
Phosphorus	0.40
Sulphur	0.05
Total	100.00

For the furnace gases, analysis by volume, with weights calculated upon the basis of 1,000 cubic feet at 62 deg. F. we have:

CO_2	11.7	1,000 cb. ft. = 13.572 lb.	contains 3.70 lbs.	carb.
CO	27.5	20.268	8.685	
H	0.8	0.042		
N	60.0	44.257		
	100.0	78.139	12.385	

All the carbon charged into the furnace must appear in the pig iron produced, and in the furnace gases evolved. The furnace charge contained 1,815 pounds of carbon, there being 1,700 pounds in the coke and 115 pounds in the limestone. The pig iron produced from the above charge contained 75 pounds of carbon as the analysis showed. Therefore, for each ton of pig iron produced, there went to the gases 1,740 pounds of carbon. From the weight of the gases given above every 1,000 cubic feet contains 12,335 pounds of carbon. Therefore, for each ton of iron produced, there will be evolved 141,000 cubic feet of gas.

The analysis of the gas shows it to be 28.3 per cent combustible, and to have a heating value of 90 B. T. U. per cubic foot, or a total heating value of 12,690,000 B. T. U. per ton of fuel.

The 2,000 pounds of coke from which this heat was derived contained 24,650,000 B. T. U. Hence, we have for the endothermic reaction of the reduction of the ore, sensible heat of slag and metal, radiation, etc., the difference between these two figures, or 11,960,000, which is to say that about one-half of the heat potential contained in the coke which was charged into the furnace is contained in the gas leaving the furnace. Furthermore, this heat potential is in the best possible condition for conversion into power; it is in the shape of a combustible gas, which after cleaning, and that without expensive or extensive apparatus, is admirably adapted for use in gas engines.

But all the gas evolved is not available for use as power; some of it must be used to heat the blast.

The analysis of the above gas shows 60.00 per cent nitrogen (derived from the air) which is by volume 79.00 per cent nitrogen. It follows that the amount of air required to produce this gas must be in the proportion of 60 to 79. That is to say, for each 1,000 cubic feet of gas made, 760 cubic feet of air were supplied. But we saw that one ton of iron evolved 141,000 cubic feet of gas. Therefore, there must have been supplied for each ton of iron 107,160 feet of air.

One thousand cubic feet of air at 62 deg. F. weigh 76 pounds. Or the weight of air per ton of pig iron is 8,144 pounds. Taking the specific heat of air at 0.25, which is sufficiently high to account for the contained moisture, we have to heat the air through 1,000 deg. F. = 2,036,000 B. T. U.

But the stoves are of low efficiency, and to be on the safe side and allow for losses in radiation and imperfect combustion, we assume an efficiency of but 50 per cent. This will double the above requirements, and give for heating the blast 4,072,000 B. T. U. With well-designed stoves of sufficient capacity this should be more than ample. For purposes other than heating the blast, there remains threfore from one ton of iron produced 8,618,000 B. T. U. The original ton of coke contained 24,650,000 B. T. U. After heating the blast we have in the form of gas 8,618,000 B. T. U. remaining, or 35.0 per cent of the total heat value of the coke.

To determine the amount of power this heat will produce, we divide the total heat available which is 8,618,000 B. T. U. by that required to produce a horse-power hour, say, 12,000 B. T. U., and we have more than 700 brake-horse-power hours as the amount available in the gas evolved from the production of one ton of pig iron. This is a conservative figure. All of this power is not available for general use. A portion of this must be used for driving the blowing engines and other machinery about the blast furnace. The amount of power required for the production of a ton of pig iron we determine as follows:

The air supplied for one ton of iron produced is 107,160 cubic feet. If we consider a furnace having a capacity of 360 tons per day or 15 tons per hour, we would require engines capable of delivering 26,790 cubic feet or air per minute.

To furnish this amount of air at 10 pounds pressure, and allowing 10 per cent for friction load, there would be required 1,200 brake horse-power. In addition to this, there are other pieces of machinery to be driven which would make the total amount of power required to operate a furnace of 360 tons capacity approximately 1,500 horse-power, but the total power available on this size furnace, as our figures indicate, is 10,500 brake horse-power per hour. Therefore, we have a surplus over and above all the requirements of the furnace of 900 brake horse-power per hour. Dividing this figure by the tonnage per hour of the 360-ton furnace, or by 15, we have, as the surplus power producing capacity of the modern blast furnace using gas engines, 600 horse-power per hour per ton of iron produced per hour, or 25 horse-power per hour for every ton of pig iron produced per day.

To secure within a reasonable degree of certainty the continuity of an available blast furnace gas supply for the operation of the power plant, without interruption, no group of less than three blast furnaces can be considered as sufficient to supply a power plant which is intended to produce power for the general market; for in any group of furnaces, at least one will at some time be out of blast for relining and another may be stopped because of a shortage of raw materials, trade or labor conditions, accidents or trouble in operation, or for other causes. With a group of three blast furnaces we are well assured that at least the surplus gas of one will always be available, and the essential condition of the power plant, that of uninterrupted service, will be afforded.

Alexander Hamilton said more than a century ago: "A government must be fitted to a nation much as a coat to the individual; and consequently what may be good at Philadelphia may be bad at Paris and ridiculed at St. Petersburg." Similarly, a system of shop management which is suited to one industrial enterprise may work only indifferently in another and be a complete failure in a third. This statement may seem to be trite and unnecessary, but as long as men are constituted as they are, and they have probably not changed much since the time of Hamilton, whenever unusual conditions develop in a shop under any form of management, suggestions as to remedies which have been successful elsewhere are at once made by people who are well meaning, but have no knowledge of the actual situation. This is empirical, and Mr. Charles Francis Adams, of Boston, in a recent paper on

"Industrial Conference" says that "in these (industrial) matters empiracy is of all things to be shunned." What is needed is a careful study by those whose knowledge of the conditions as they exist constitutes them as most competent to analyze the situation and deduce proper methods of procedure.

THE "ADOS" AUTOMATIC CO_2 RECORDER FOR BOILER FURNACES.*

THE scientific control of boiler furnaces as a means of obtaining a high factor of efficiency and economy is a necessity which has long been appreciated by steam users, and although various devices have been designed for the analyzing of the gases in boiler flues for the purpose of determining the quantity of CO_2 contained therein, the majority have failed. A new type of recorder, however, has been designed in England, and has been submitted to extensive and practical operations in numerous manufactories and power-generating stations with success.

This apparatus, which is automatic in action, is known as the "Ados." Its action is based upon the well-known fact that a solution of caustic potash absorbs CO_2. A quantity of the flue gases of the furnace to which it is attached is pumped through the apparatus. A portion is bottled up, measured, and passed through a solution of caustic potash, which absorbs all the CO_2. The quantity of gas so absorbed, which represents the percentage of CO_2, is determined, and recorded on a diagram by means of vertical lines, the cycle of operations occurring every five minutes, so that twelve indications of the working of the furnace may be obtained each hour. The tops of the various lines form a curve which shows the fluctuation of the percentage of CO_2 in the flue gases during the time the recorder has been in operation.

In practice about 1.3 times the theoretical quantity of air are requisite to obtain perfect combustion. If this proportion is exceeded, the fuel required to heat the excess of air to the temperature of the furnace is wasted; and while in practice the percentage of carbonic acid gas in flue gases should be approximately 15 per cent—the theoretical maximum of 21 per cent being impossible of attainment—the passage of a great volume of air through the furnace will result in the percentage being considerably below this figure. The only means of determining this percentage is by means of a recorder.

The "Ados" apparatus is simple in construction and operation, easily comprehended, and requires no skill or training in attendance, while it has the further advantage of not becoming deranged or fallacious in its working, through failure of the mechanism. The apparatus consists essentially of three fundamental sections—the motor, gas pumps, and the analyzing and recording apparatus.

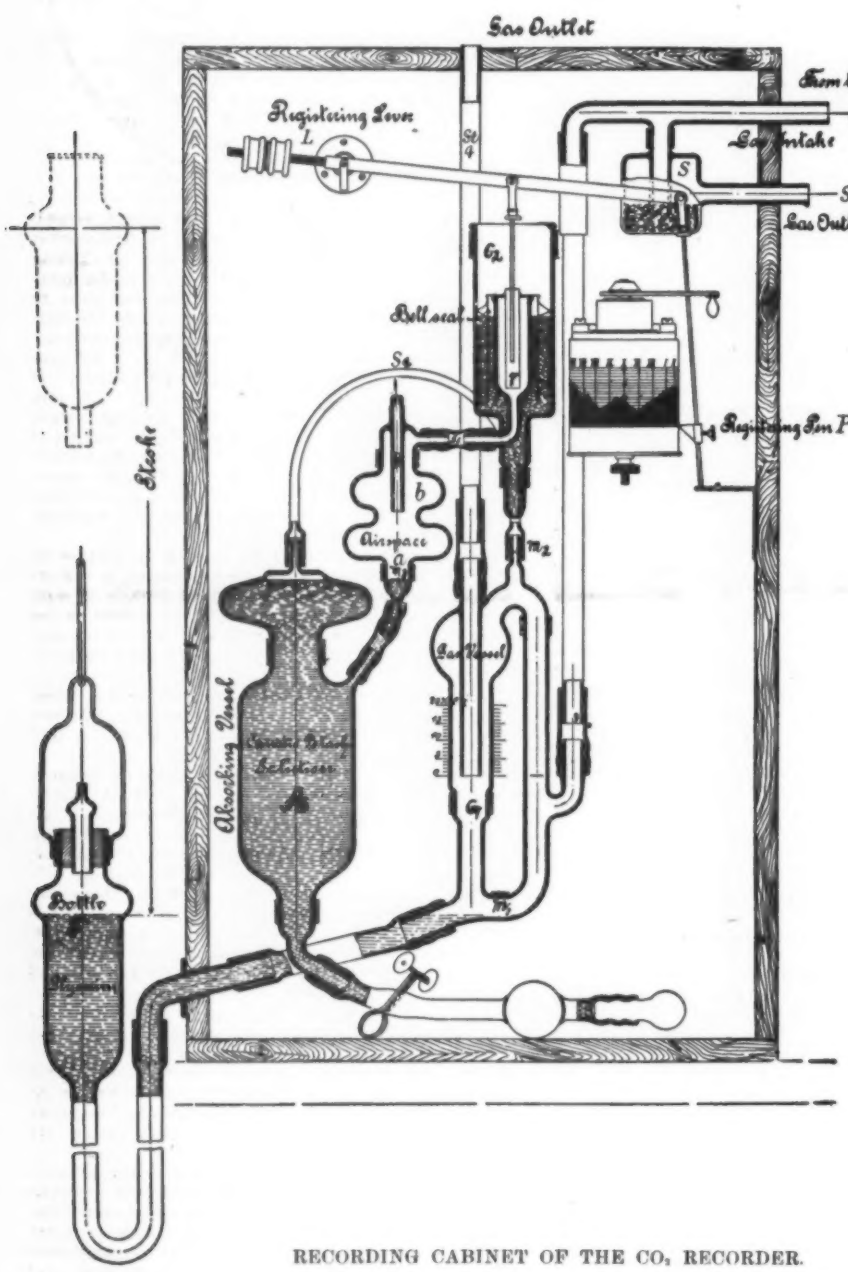
The motor comprises a tank, bell, and fittings. The interior of the bell is connected with the chimney by means of a tube, and the draft in the chimney creates a vacuum under the bell, which is pressed into the tank under atmospheric pressure. Air is then admitted into the bell by means of an automatic valve, causing it to return to its normal position. This motion is carried out at intervals of five minutes, and its function is to raise and lower a bottle filled with glycerine and to drive a pair of specially designed pumps, which force the gases received from the flue through a tube from the chimney through the analyzing and recording apparatus. So long as there is any draft in the chimney, the motor will work without any further assistance or supervision. The power sufficient for actuating the motor is simply a draft of half an inch of water. The gas pumps comprise two cylinders, which dip into oil tanks rising and falling alternately, drawing flue gases from the chimney and forcing them through the recording apparatus. The rising and falling motions are controlled by wires attached to the oil pumps passing over their respective pulleys and round a drum on the large pulley, by which their motion is governed by the motor. The level of the water in the tank is two inches below the spout; and in order to avoid discrepancies, or failure of action arising from water losses through evaporation, a film of oil is distributed on the surface of the water. Below the oil pumps are arranged a series of glass valves filled with glycerine to marks indicated, and connected with rubber connections, finally leading to the recorder and through these glasses the flue gases pass.

The analyzing and recording apparatus comprise fundamentally a glass tube acting as a measure to bottle up 100 cubic centimeters of gases, a bottle containing a solution of caustic potash which absorbs the CO_2 gas, and a pen indicating upon a calibrated diagram the percentage of carbonic acid gas ascertained. The bottle *A* is filled with caustic potash solution consisting of 395 parts by weight of caustic potash and 875 parts by weight of distilled water, giving a specific gravity of 1.27, up to mark m_3. The level of this solution is regulated as desired by means of a squeezer and an India-rubber ball. The vessel G_2 containing a measuring brass bell is filled with glycerine to a point indicated below the mouth of the bell, so that no glycerine may enter. The valve *S* is then filled with glycerine until the inner tube is sealed. The pen *P* is actuated by the lever *L*, which is balanced by an adjustable counterweight. At the left of the recorder is another vessel *F*, which is attached to the counterweight and wire connected with the bell of the motor, and which is lifted up and down by the motion thereof. This vessel is brought to the lowest point of its stroke, and is then filled with glycerine in the proportion of one part of glycerine to two parts of water until the liquid reaches the point m_1.

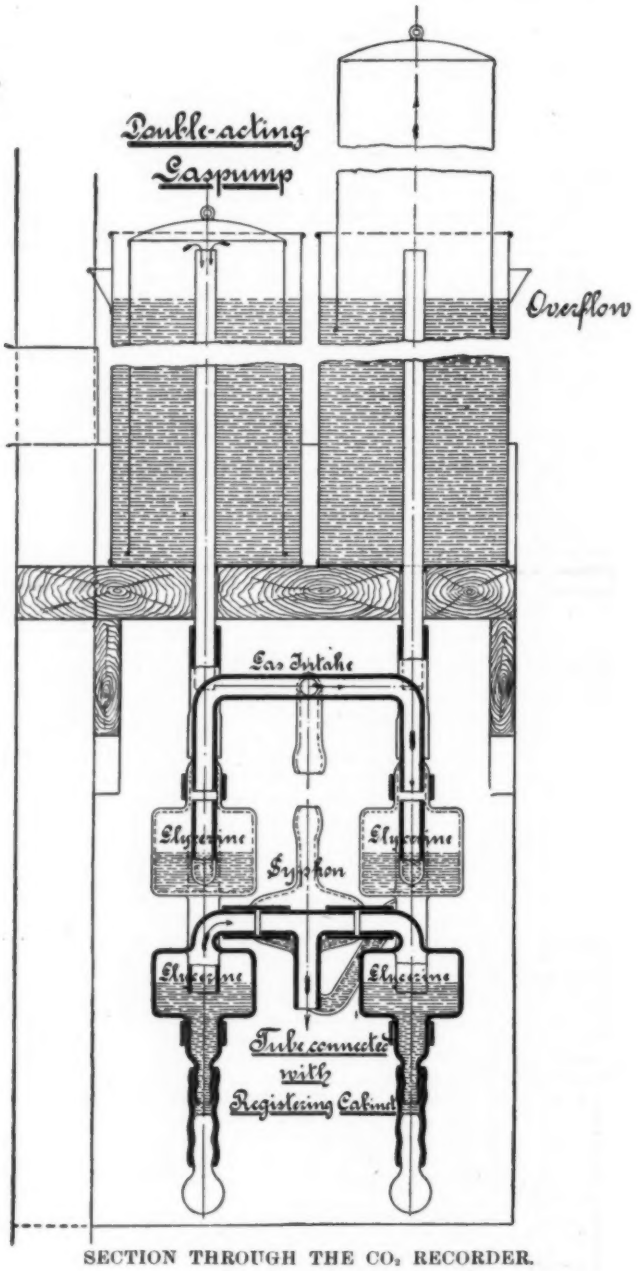
Before the gases enter the apparatus they pass through a filter, which is placed near the point at which the chimney flue is tapped. This filter is filled with wood wool, which serves to arrest the passage of any soot, dust, or other impurities suspended in the furnace gases and to prevent them entering the apparatus. The filter is covered with a lid dipping into glycerine, thus constituting a perfect seal, so that none of the gases drawn from the flue can escape. Fixed behind this filter is a water collector, which serves to receive any condensed water, and the entrance of air at this point is prevented by filling the chamber with water.

The operation of the apparatus is as follows: As already mentioned, the glycerine vessel *F* being attached to the motor rises and falls periodically. When the vessel is at its lowest or normal point, the glycerine extends to the level m_1. When the vessel is raised to its highest point of the stroke, the level of the liquid is raised to m_2, and the cubic contents of the tube between *O* on the scale of the measuring tube and m_2 is 100 cubic centimeters.

The incoming gases enter the apparatus through the tube St_3, and the glycerine bottle *F* being raised, the level of the glycerine rises from m_1 and seals the lower part of the vessel *G* into which the gases have passed. The glycerine continues rising until it touches



RECORDING CABINET OF THE CO_2 RECORDER.



SECTION THROUGH THE CO_2 RECORDER.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

the mark *O*, and 100 cubic centimeters of CO_2 gas are bottled up, and their exit through the tube St_4, through which they finally escape, is cut off. The level of the glycerine still rising, it enters the gas vessel *G*, and the gas within that receptacle is thus forced through the tube *S*, into the bottle *A*, which is filled with the caustic potash solution, and this absorbs the CO_2 gas present in the 100 cubic centimeters of flue gases. The non-absorbed volume of gas replaces an equal volume of caustic solution, and this is forced up into the globe *a* and seals the tube *R*. It can now rise only in the chamber *b*, and in so doing it presses the air present in this globe into the bell *T*, which rises and thus lifts the lever *L*, with which the recording pen is connected. Naturally, the less carbonic gas absorbed by the caustic solution in bottle *A*, the higher the bell *T* and consequently the recording pen will rise.

Directly the glycerine vessel *F* reaches the length of its stroke and commences to return, the level of the glycerine begins to recede toward M_1, its normal point. The flue gases imprisoned in the glass vessel *A* return into vessel *G*, and directly the mouth is open once more, by the return of the glycerine beyond that point, are ejected through the outlet St_4 by the action of the pumps. The apparatus is exhausted of every trace of a preceding gas charge, and owing to the fact that the pumps deliver about twenty times the volume required, the same gas is never analyzed over again.

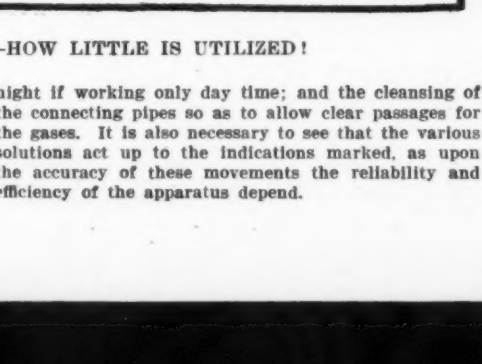
The record chart is calibrated in per cents from 1 to 20, and the time is recorded on it. For every per cent of CO_2 absorbed, one cubic centimeter of air less is displaced, and the registering lever rises one per cent on the chart. Consequently, when there is no carbonic gas present, the pen rises to the top of the chart. The tops of the various vertical strokes recorded upon the diagram constitute the CO_2 curve. The process can be carried out at any intervals desired from five minutes to ten minutes, according to the speed of the motor, which speed can be regulated as required. The apparatus works entirely automatically, and requires no attention whatever. In order to stop its operation, it is necessary only to remove a stopper provided for this purpose in the tube of the tank.

The value of such an apparatus will be realized by every steam user, and it is of great assistance to stokers, as it enables them to determine accurately the percentage of air for combustion that is required to procure the most efficient and economical working of the furnaces. It also constitutes a valuable adjunct to mechanically-fired furnaces, since it proves an effective means of controlling them. In several instances where tests have been carried out with this apparatus in connection with furnaces fired in this manner, the amount of CO_2 gas has been found to be as low as 8 per cent, whereas had the efficiency been maintained to some 13 per cent, a 9 per cent economy in the fuel would have been effected. In an annual consumption total say 10,000 tons, which is by no means an extravagant consumption for twelve months in a large steam-raising plant, this waste would aggregate 900 tons, which is a considerable amount. The apparatus is also applicable to suction gas-fired boilers, where the same conditions apply.

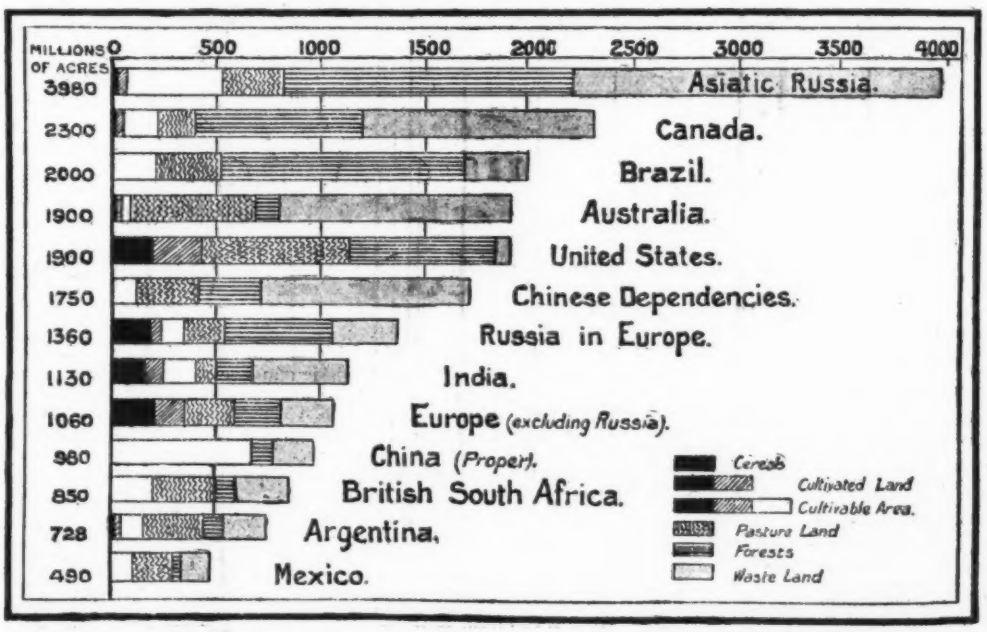
The recorder occupies but little space, being only 6 feet in height by 3 feet in width and 2 feet 6 inches in depth. It can be erected in any suitable position, either in the boiler house, or in the case of a large plant, it can be erected in the office of the manager of the department, who can thus instantly learn whether his furnaces are working with the maximum efficiency. The only precaution necessary to observe is not to place the apparatus in a too dusty or too hot position. Thirty feet from the furnace is an ideal location, and under such conditions the suction gas pipe need only be ½ inch in diameter. If placed at a greater distance from the fires, a ¾-inch pipe is requisite.

The apparatus can also be utilized to great advantage for testing furnaces. Although the waste in fuel will generally be due to faulty regulation of the air admittance to the furnace on the part of the stoker, the cause may arise from the excessive size of the furnace, or to the presence of cracks in the masonry, which results will be accompanied by a steady low reading of CO_2 gas despite alterations in the air supply. When the defects are remedied, the reading will indicate immediately a higher percentage of carbonic acid gas.

The only attention that the apparatus requires is the renewal of the caustic solution once a week if the furnace is working day and night, or once a fortnight if working only day time; and the cleansing of the connecting pipes so as to allow clear passages for the gases. It is also necessary to see that the various solutions act up to the indications marked, as upon the accuracy of these movements the reliability and efficiency of the apparatus depend.



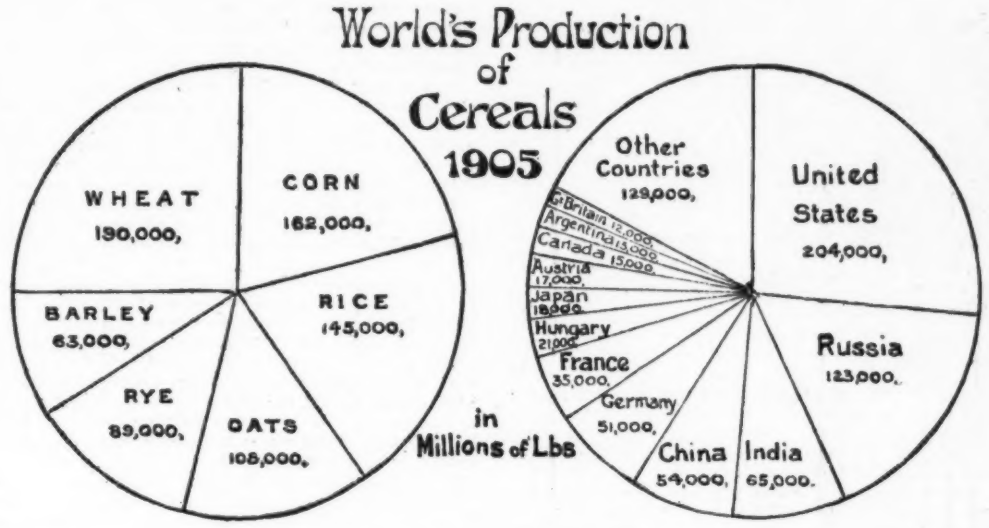
ACREAGE UNDER CEREALS IN EUROPE COMPARED WITH UNITED STATES.



THE WORLD'S LAND SURFACE—HOW LITTLE IS UTILIZED!

THE AGRICULTURAL DIVISIONS OF THE WORLD.

THE diagrams which we publish, illustrating some of the principal facts of the world's agriculture, have been reproduced from originals prepared by the Philadelphia Commercial Museum.



Wheat is seen to be the king of all cereals, exceeding any other in quantity produced and in the market value of the product. Taking the average production of the leading cereal for the last five years, the quantity of wheat is 3,160 million bushels, equivalent to 190,000 million pounds. Three nations produced one-half of this—the United States, 660 million bushels; Russia in Europe, 541 millions; and France, 328 millions. India produced 286 million bushels; Italy, 159 millions; Germany, 128 millions; Hungary, 120 millions; Spain, 115 millions. A number of the important exporting nations have not, comparatively speaking, a large production of wheat, but owing to their small population they have a large surplus for export. These are Argentina, 101 millions; Canada, 91 millions; Asiatic Russia, 90 millions; Roumania, 75 millions; Australasia, 54 millions.

Corn is next in quantity, though not in number of bushels. The weight of the corn produced is 162,000 million pounds. Of the 2,886 million bushels of corn, 2,286 millions, or about three-fourths, is raised in the United States. Argentina, although averaging only 112 million bushels, sometimes exports more than the United States.

Corn, under the name of "maize," is the one cereal that the Old World obtained from America. It is now grown in China, India, Italy, Roumania, Africa, and other warm countries.

Oats exceed all others in the number of bushels, but owing to the lightness of the grain, the 3,371 million bushels only weigh 108,000 million pounds. This is due to the fact that there are only 32 pounds to a bushel of oats against 60 to wheat, 56 to corn and rye, and 48 to barley. The United States produced 871 million bushels, and Russia 825 millions; these two combined producing more than one-half of the world's crop. Germany produced 494 million bushels; France, 268 millions; Canada, 204 millions; United Kingdom, 187 millions, and Austria and Hungary combined, 196 millions.

Of the crop of rye, Russia produced 840 million bushels, or more than one-half, and Germany 372 millions, or more than one-fourth.

Barley, or brewer's grain, is largely produced in those countries, or parts of countries, where grapes for wine are not cultivated. Russia produced 297 million bushels; Germany, 145 millions; United States, 114 millions; Japan, 80 millions.

Rice is probably second only to wheat in the quantity produced. There are no statistics for the production of the cereals in China. The best authorities estimate the production of rice in China at about 54,000 million pounds, which is a greater amount than the 48,000 million pounds which official returns give for India. There is a mistaken idea in regard to the consumption of rice in China. M. Huc says that in the northern provinces rice is as rare a dish as in France, being found only on the tables of the rich, but in the south it is the chief food of millions. Millet is an important food crop in India, China, Russia, Africa, Japan, and Italy. A species known as Kaffir corn is also grown extensively in Kansas. India produced 542 million bushels, China, a large quantity, but probably not so much as India, Russia in Europe, 78 millions, Asiatic Russia, 15 millions, Japan, 12 millions, United States, 5 millions.

The circle by countries shows that the United States far exceeds any other nation in the production of cereals. If the quantity of millet produced in India were included, its cereal production would be nearly 100,000,000,000 pounds. If the quantity of grains other than rice produced in China were obtainable, its total production would probably be second only to that of the United States. Some exporting countries, like Hungary, Argentina, and Canada, rank very low in the list of grain producers.

Europe, exclusive of Russia, with its nearly 300

millions of population, is exceeded by the United States in the millions of acres cultivated, and in the bushels of cereals produced. Yet, notwithstanding this, the total value of the farm products of this region far exceeds that of the United States at the present time.

THE MEASUREMENT OF RESEMBLANCE.*

By SIR FRANCIS GALTON.

AT the distance of a few scores of paces the human face appears to be a uniform reddish blur, with no separate features. On a nearer approach specks begin to be seen, corresponding to the eyes and mouth. These gradually increase in distinctness, until at about thirty paces the features become so clear that a hitherto unknown person could thereafter be recognized with some assurance. There is no better opportunity of observing the effects of distance in confounding human faces than by watching soldiers at a review. Their dress is alike, their pose is the same, the light falls upon them from the same direction, and they are often immovable for considerable time. It is then noticeable how some faces appear indistinguishable at distances where great diversity is apparent in others, and the rudely-defined idea will be justified that the distance at which two faces are just mistakable for another might serve as a trustworthy basis for the measurement of resemblance. The same may be said of obscurity, of confused refractions, and of turbid media; but I shall confine myself almost wholly to the effects of distance under the conditions of ample light and a transparent atmosphere. Beyond this I shall say nothing, except in one paragraph almost at the end.

The scale of the features has, of course, to be taken into account. This is of much less importance in living persons than in portraits, because the differences in scale of the adult human face are not very great, whereas those in photographs and paintings—ranging as they do between miniatures and life-sized portraits—are so. It is necessary to adopt a *facial unit*, based on some specified dimension. That which I use is the vertical distance between the middle of the line that joins the pupils and the parting of the lips. It is unaffected by head-dress or by the thickness of the hair on the top of the head, while its lower termination can be located in a bearded face more accurately than the chin. I call this u. If the portraits have different units, they are distinguishable as u and u'. If d and d' be the critical distances at which mistakability first occurs, then u/d and u'/d' are necessarily equal, and either of them would serve as a measure of mistakability; but as u is very much smaller than d, this fraction would always be a decimal preceded by one or two zeros. Therefore, I take the index of mistakability, which I will call N, as $=1{,}000\ u/d$. It is, however, convenient to measure u and d by different scales; u in millimeters, distinguishing it as u_m; d in centimeters, distinguishing it as d_c. Then $N = 100\ u_m / d_c$.

Of course, N could be expressed by the arc or angle of which u/d is the chord, but it would be a roundabout method, as angles could not be measured directly without special and troublesome apparatus. I find it very convenient for my purposes to employ a nomenclature for chords based on that of the metrical system, d, the distance, being the radius or "rad." So a chord $=1/100$ becomes a "centirad," and that $=1/1{,}000$ a "millerad." A centirad is the cord of 34.4 minutes of a degree, and, therefore, a trifle larger than the apparent diameter of the sun or moon. It is equal to the apparent size of one-tenth of an inch at 10 inches distance from the eye, which is a convenient distance for reading small type. A millerad which subtends between three and four minutes of a degree, and is equivalent to 1/100 of an inch seen at 10 inches, is as small an interval as can usually be detected in photographs without scrutiny, though a normal eye is able to distinguish one-third or even one-fourth of that interval between sharply defined objects.

Mistakability is only an approximate measure of resemblance, for it depends more on the scale of the distinguishing features than on the amount of difference of those features. This peculiarity is well exemplified, though greatly exaggerated, by what is seen in the time-tables hung up by railway stations. From across the road, say, they all appear alike as a shade of uniform gray. On approaching nearer, differences are observed in the headlines; nearer still, varieties in paragraphing come into sight, and at a reading distance the figures are all simultaneously distinguishable. This experience is partly, but only partly, applicable to human faces. Those that are alike are certainly distinguishable at shorter distances than unlike ones, and I notice no excessive clustering of values closely around particular values of N in my results, which there would be if mistakability always occurred near a particular stage, such as that at which the whites of the eyes cease to be visible, or at twice or three times that distance.

A strong likeness in small details may so dominate the perception that a want of likeness in larger features is overlooked. Here the distance of maximum mistakability will be small, the portraits appearing more unlike when removed further off, and the small details cease to be visible. Extreme cases of partial likeness, whether in contour or in detail, would, of course, be noted and allowed for. With these exceptions the index of mistakability appears to be a fair, even, as I think, a close, approximation to an index of resemblance when the quality of the observed likeness is recorded by appropriate letters, as will be described later on.

The observational value of mistakability lies in its asking a simple question which different persons would answer in the same way, when they had become familiar with the method. On the other hand, *likeness* includes mutual *suggestibility*, a highly complex perception dependent on the mind of the observer, and consequently appreciated differently by different observers, as is notoriously the case.

The apparatus I now use with ordinary photographs acts very well, but I wasted much time before I contrived it, and more before sending it to be made in a workmanlike manner. I think it could still be improved, so I will describe, not my own, but such as I should order if I required another one.

It is a long, thin, light body or framework 6½ feet (2 meters) long, 10 inches (25 centimeters) wide, and 2 inches (5 centimeters) deep, which admits of being divided for sake of portability. It stands on two folding supports 2½ feet apart, which fold back when out of use; when in use they can be clamped to any ordinary table. These raise the long box in a sloping position, the end toward the eye being at the most convenient height for a person seated on a chair, but the further end being lower, because it is easiest to look somewhat downward. Two rollers, *A* and *B* (Figs. 1 and 2), run independently on a horizontal axis at one end of the box, and two corresponding ones, *a* and *b* (Fig. 2) at the other end. A light sledge that slides on the top of the box is harnessed in front to a tape graduated in centimeters, which passes over and round *A*, back to and around *a*, and thence forward to the back of the sledge. (By inadvertence the path of the tape between the lower margins of *A* and *a* has been omitted in Fig. 1. The reader might dot it with a pencil.) A similar sledge and tape is adapted to *B* and *b*. The tapes lie half an inch above the box (Fig. 1), and can be manipulated by the hands severally, so either or both sledges can be easily pulled either backward or forward while sitting in the chair, and their distances from the rollers at any moment be read off on the graduated tapes. (A winch and handle are superfluous.) The photos are mounted on two easily detachable standards (Figs. 1 and 2), with clips at the bottom to hold them (not shown in the diagram), and standing on circular bases. These fit quite loosely into shallow hollows in the tops of the sledges. The standards can be lifted out, the photographs inserted, and the whole replaced with perfect ease. The circularity of the bases of the standards enables either of them to be set a little askew, which is convenient when the broad, full face of one portrait has to be compared with the narrowed, three-quarter face of another. A board stands vertically across *A* and *B*, and above them as a bridge. An eye-slit of half an inch width runs below its upper edge (Figs. 1, 3, and 4), through which the photos are viewed, and from which the distances of the sledges are reckoned. A ledge one inch below the eye-slit (Fig. 1), with a parapet a little less than one inch, forms a long, narrow groove into which light rectangular frames of wood, each with a spectacle lens in it, can be slipped and will stand upright (Figs. 1 and 4). I chiefly use lenses of 12, 24, and 48 inches; my eye can accommodate its focus to intermediate distances, but I possess others which are sometimes serviceable. Younger persons with normal eyesight would want no lenses at all. The length of the box suffices for cabinet-size photos. An opera glass reversed enables it to be used with larger ones, the minifying power of the opera glasses at various short distances having been ascertained.

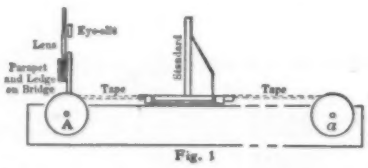


Fig. 1

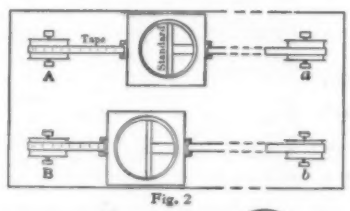


Fig. 2

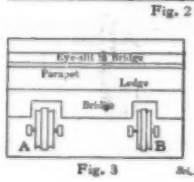


Fig. 3

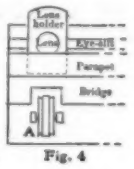


Fig. 4

Mutual mistakability may occur under any one or more of the following conditions, which are to be noted, together with further remarks:

a a. The portraits are apparently exact copies or reductions on different scales.

a. They appear to be portraits of the same person at about the same age, though differing in pose and dress.

b. They would be mistaken for portraits of the same person, even though they differ in sex and considerably in age, if the hair had been cut and dyed alike, and the dress arranged in the same way.

c. As above, if much disguised, as for theatrical personations.

b—*c*. Applies to cases intermediate between *b* and *c*.

P. Their resemblance is partial only, being confined to special features.

The following little table saves trouble in operating; my own is more extended:

Values of d_c in terms of N and of u_m $\left(d_c = \frac{100\,u_m}{N}\right)$

N	u_m									
	1	2	3	4	5	6	7	8	9	10
5	20	40	60	80	100	120	140	160	180	200
7.5	15	30	45	60	75	90	105	120	135	150
10	10	20	30	40	50	60	70	80	90	100
15	7	15	22	30	37	45	52	60	67	75
25	5	10	15	20	25	30	35	40	45	50
20	4	8	12	16	20	24	28	32	36	40

The procedure adopted after many trials was to measure the u_m of each portrait to the nearest half-millimeter and to write it below. Then to mount the two portraits, each on a separate sledge if their facial units differed, otherwise on the same. When they differed, the facial unit of the one about to be used for d_c was distinguished as u_m, the other was in brackets as (u'_m). Next, after referring to the above table, to send them to their respective d_c for $N=5$, to consider them carefully, and to note the result. Then to do the same for $N=10$, and so on, until the eye became familiarized with the differences between the portraits. Finally, guided by these provisional attempts, to fix on the suitable index and letter, adding such remarks as may seem wanted.

I became gradually more consistent in judgment, as ascertained by comparing the results on different days, but have felt all along that it would conduce to trustworthiness if two or more companions worked together and criticised one another, and recorded their common verdict.

A very brief example will suffice. Usually an entry consists of more lines followed by general remarks.

Two Sisters, Registers (so and so).
$u_m = 8.5$; $(u'_m = 9.0)$.

N	d_c	Character of Likeness.
5	170	*b*
10	85	Nearly *b*
After trials.	115	Just *b*

Accept $N(b) = \frac{80}{115} = 7.4$

I will add a few words on dealing with mistakability caused through obscurity or other hindrances to clear vision. I prepared test cards, each containing numerals printed in different types, and, having ascertained by experiment the value of d_c for each kind of type when just able to read it in a clear light, wrote that value boldly by its side. An appropriate test card was put by the side of the portraits, and at the time when the portraits themselves were just mistakable, the written d_c of that row of figures which were just unreadable, was noted. The value of d_c remains constant whatever be the character or amount of the optical hindrance. If the hindrance increases, the portraits and the accompanying test card must be brought nearer to the eye. They increase simultaneously in legibility. The written d_c will always show what the d_c would be in a clear light.

The applications of the process are numerous, as must always be the case when a hitherto vague perception is brought within the grip of numerical precision. To myself it has the especial interest of enabling the departure of individual features from a standard type to be expressed numerically. The departure may be from a composite of their race, or from a particular individual. The shortcomings of a pedigree animal from a highly distinguished ancestor could be measured in this way. Many other examples might be given.

ARE CRYSTALS ALIVE?

A COMMUNICATION of unusual interest was made by Prof. O. Lehmann at the last Congress of German Physicians and Physicists at Stuttgart.* It refers to some new and striking analogies between the development and characteristics of crystals and those of the lowest living organisms, and demonstrates the fact that no hard and fast line of demarkation can be drawn. This has been suspected by Haeckel for some time past. That ice crystals imitate vegetable forms is known to every child. That they grow we all know. They have also a certain recuperative power, and they require a nucleus or germ to start their growth. They have, in addition, a power of absorbing foreign substances, as when salammoniac crystals absorb chloride of iron from a solution, and become darker than the solution itself. In the course of the process they "poison" themselves, and their growth becomes very irregular and imperfect.

But one essential difference remains. Animals are semifluid, or partly so, whereas crystals are supposed to be essentially solid bodies. This supposition now no longer holds good, for Prof. Lehmann and some other chemists have succeeded in producing truly liquid crystals. Of these about fifty varieties have become known up to the present. The first kind discovered consisted of a modification of silver iodide

* Nature.

* See Physikalische Zeitschrift, November 1, 1906.

which is stable above 146 deg. C. It is a viscous liquid, but under the microscope it reveals a distinctly crystalline structure. The most familiar example is soft soap, which consists of innumerable soft crystals. Some new chemical preparations with alarming names show this structure more strikingly. Vorländer's para-azo-oxy-benzoic-ethyl-ester is seen to consist of numerous crystals in constant motion. Whenever two crystals collide they coalesce with a jerk, just like drops of liquid. Another substance exhibits soft crystals in long straight columns with sharp facets. Gattermann's para-azoxy-phenetol is as liquid as water, and occurs in drops; but each drop possesses a structure which is easily proved to be of a crystalline character. Seen in the direction of the axis of symmetry, each drop appears to have a round nucleus; but seen in a direction normal to this axis, the nucleus appears like a bi-convex lens. Both these structures are unreal. They are products of refraction. But they prove that the drops are not isotropic.

When two drops collide they form one drop; but the new drop has two nuclei, with a third between them, and this lasts for several minutes.

In polarized light the drops show well-marked dichroism, and between crossed Nicols they show beautiful interference colors, just like solid crystals.

On squeezing or bending such a liquid crystal and releasing it, it resumes its original shape after a short time, just as an amœba would do. Two species of crystals may be "crossed." Thus, two varieties of cholester-thyl-caprinate may be combined in a structure recalling the luster of a butterfly's wings.

These phenomena, striking as they are, do not exhaust the wonders of liquid crystals. Vorländer has observed exceedingly curious phenomena in a substance called para-azoxy-cinnamo-ethyl-ester. Under suitable conditions, the crystals take the shape of spheres flattened on one side. When two such drops meet three different things may happen. Either the drops are in the same position—say with both bases downward, and one on top of the other; then they coalesce into one round drop. Or the bases touch; then they form a twin or couple without running together. When they meet in any other way they form a drop with two flat surfaces. The "copulation" of two individuals has a remarkable counterpart in the process of "budding," which is sometimes observed, small buds appearing on the flat surfaces, and dropping off when they reach a certain size.

Further, the drops often make a chain resembling a bacterium, growing by intussusception instead of by apposition. These rods may be spirals, and are often seen in serpentine motion. Eventually they break up, and each fragment develops into a perfect individual.

These curious experiments, which were exhibited at the congress, make it practically impossible to assign a definite limit to vital phenomena, or to say where organic matter ends and inorganic matter begins.

GEOMETRY OF THE HINDUS.

THE researches of the learned have brought to light astronomical tables in India which must have been constructed by the principles of geometry, but the period at which they have been formed has by no means been completely ascertained. Some are of opinion that they have been framed from observations made at a very remote period, not less than 3,000 years before the Christian era; and if this opinion be well founded the science of geometry must have been cultivated in India, to a considerable extent, long before the period assigned to its origin in the West, so that many of the elementary propositions may have been brought from India to Greece. The Hindus have a treatise called the Surya Sidhanta, which professes to be a revelation from heaven communicated to Meya, a man of great sanctity, about four millions of years ago; but setting aside this fabulous origin it has been supposed to be of great antiquity and to have been written at least two thousand years before the Christian era. Interwoven with many absurdities this book contains a rational system of trigonometry, which differs entirely from that first known in Greece or Arabia. In fact, it is founded on a geometrical theorem which was not known to the geometricians of Europe before the time of Vieta, about two hundred years ago. And it employs the sines of arcs, a thing unknown to the Greeks, who used the chords of the double arcs. The invention of sines has been attributed to the Arabs, but it is possible that they may have received this improvement in trigonometry, as well as the numeral characters, from India. The only fact here asserted which bears upon the question of the civilization of the Hindus is that of their using the sines of arcs instead of the chords of the double arcs. Suppose that they invented this method. It proves nothing beyond what all men believe—that the Hindus made a few of the first steps in civilization at an early period, and that they engaged in those abstract speculations, metaphysical and mathematical, to which a semi-barbarous people are strongly inclined. The Arabians were never more than semi-barbarous. The Greeks were no better at the early age when they were acquainted with the elementary propositions of geometry. If the Greeks or Arabians invented in the semi-barbarous state the mode of computation by the chords, what was to hinder the Hindus from inventing while semi-barbarous the mode of computing by the sines of arcs? This is upon the supposition that the mode of computing by sines and the elementary propositions on which it depends really are original among the Hindus. But this seems not to rest upon very satisfactory proof, when it is barely inferred from the use of chords by the Greeks; and the possibility alone is asserted of the Arabians having derived the knowledge from the Hindus.

ELECTRICAL NOTES.

The Milan Traction Company has recently installed a junction line between the city of Spezzia and the suburban town of Portovenere, over a length of 2½ miles. The overhead wire system is used with a newly-designed type of road omnibus. The trolley wire is double, and the two wires are suspended at a height of 22 feet above ground and are spaced about 2 feet apart. The wires are supported either by cross-wires stretched between poles at the sides of the road, or upon brackets. One of the wires is connected to ground. The voltage used here is 500 volts, and the current comes from the generating station of the Spezzia traction lines. An omnibus is used which holds fifteen passengers and weighs 1.6 tons. It carries a motor which is placed against each of the rear wheels, thus operating each wheel independently. The motors give about 5 horse-power each. A controller on the car gives four running speeds and two back speeds, also an electric brake. A very strong hand brake also acts on the rear wheels. The cars are electrically lighted and heated. Current is taken from the overhead line by a form of roller trolley on the Cantono system. The maximum speed of the cars is 15 miles an hour. The omnibus runs over the ordinary road, and no rails are used on this line. Means are provided so as to allow for a free movement of the car.

The Schwerin municipal electric station is one of the plants in Germany to use producer gas, and at present it is in very successful operation. Producers, engines and dynamos, and storage batteries are installed in separate rooms. The gas motors are of the Kieling design, and in the dynamo room are erected two of these engines which are coupled in each case on the same shaft with a dynamo of 300 horse-power. In the same room is a rotary converter group which is used for charging the batteries. The gas engines are of the single-cylinder pattern and operate at 125 revolutions per minute, while the dynamos deliver current at 450 volts. Another room contains a battery of 268 cells. All the wiring in the town is underground, and it has about 50 miles total length. Among other gas engines in use in Germany within a recent period may be mentioned the Deutz system, and one particular feature lies in the fact that it uses lignite briquettes in the producer. When in the natural state the lignite contains from 40 to 60 per cent of water, but after drying this is reduced to 20 per cent. Such a plant, consisting of a producer, gas-holder, and engine is used in many cases for running dynamos. In France a successful gas engine plant is run by the Beaume and Marpent car shops, and they are able to burn all their wood scrap in a special producer which is designed for the purpose on the Riché system. The gas is used in a number of engines which are coupled to dynamos, these groups being of different capacities ranging from 160 to 60 horse-power. In this way the company obtains a large amount of current for use on its premises for lighting and electric motors, with a minimum cost.

Among the exhibits of the Compagnie Internationale d'Electricité de Liège at the Milan Exhibition was a small switching locomotive, built to the order of the Belgian government, working on the Pieper "automixte" system. The arrangement is, in general, similar to that employed on the "automixte" automobiles and omnibuses, already described in these columns. It will be remembered that in this system a gasoline engine is employed which drives the vehicle through a magnetic clutch without any mechanical change speed gear, and that a machine, which can act either as a dynamo or a motor, is mounted on the same shaft and serves to charge a small buffer battery when the engine is running light, or to act as motor, taking current from the battery and supplying additional torque to that of the engine at starting and other times of heavy load. In the case of the locomotive, which is described in l'Eclairage Electrique the engine is of the four-cylinder type rated at 30 brake horse-power, and the dynamo has an output up to 20 kilowatts. An arrangement of magnetic clutches, which puts into action one or other of two sets of bevel gear, forms the reversing gear, and an electro-magnetic brake is also provided. The drive is taken by reduction gearing to a transverse shaft midway between the two driving axles, which is provided with cranks connected to the centers of the coupling rods on either side of the locomotive. As in the case of the road automobiles, the whole of the control is effected by one lever, but the speed control is slightly different, as the dynamo is provided with two commutators which can either be placed in series or parallel, in addition to the variations in the excitation. The regulation of the engine is entirely automatic, and is effected, as in the case of the automobiles, by a throttled valve controlled by a solenoid.

There seems to be no doubt that electric trains will be adopted before long upon the Vienna Metropolitan lines. At present the road, which is in double track, runs for a considerable length in subway, and for this reason the use of steam locomotives has proved to be a great drawback on the line, seeing that the part of the public which would use the Metropolitan line for short distances are deterred from so doing by the unpleasant nature of the trip in the smoky tunnels, and naturally prefer the surface tramways whenever these can be used. To avoid this difficulty it was lately decided to take steps toward changing over the line to electric traction, following the example of many of the large cities of Europe. The Krizik firm, of Prague, designed and built a new type of electric locomotive which is expected to meet the local requirements, and it is soon to be run upon a trial section of the line. Such a locomotive must take a 140-ton train up a maximum grade of 1 in 30. Given a mean of 570 horse-power, it must have at least 700 horse-power available. As there are twenty-one trains on the road at once, the whole power need is figured at about 15,000 horse-power. The total length of the tracks is 17 miles, and trains are to be run at 2½ minute intervals. As regards the electric locomotives, the distinguishing feature about them is that each of the two axles carries two direct-current motors placed on either side and geared to it. An overhead trolley formed of a hinged frame carrying a horizontal contact rod at the top takes 3,000-volt current from an overhead wire, giving 750 volts for each of the motors when they are run in series. The motors are of the ironclad type. Each one is designed for 130 effective horse-power, working upon 750 volts, 134 amperes and 545 revolutions per minute. The entire locomotive weighs about 30 tons, counting 15 tons for the electric outfit. Newly-designed controlling apparatus is one of the features of the system.

ENGINEERING NOTES.

The engines of the Otto type, as constructed by leading manufacturers, have been developed to a state of high perfection. Their deficiencies and incidental phenomena have been so far eliminated that the enthusiastic advocate of gas power is apt to overlook them entirely. Yet of ten indicator cards taken under identical conditions from the same engine, every one will reveal its fundamental weakness, namely, the impossibility of controlling the combustion which is the most important function of the working process. The irregular and imperfect mixing of the charge constituents, the possibility of premature ignition and after burning are drawbacks of the working cycle of gas engines. Various attempts to improve on the working process as carried out in standard engines (as by prolonged expansion, compounding, and water injection) have proved to be entries on the wrong side of the balance sheet. The drawbacks common to all of these so-called improvements are increased bulk, weight, first cost, and negative work expanded. The best method of prolonging expansion is by high compression of the dynamic charge before combustion. The most economical way of reducing heat losses through the exhaust is by utilizing the same for raising steam in an exhaust boiler. As high as 160 pounds per square inch can in this way be generated and used for factory heating or other purposes. Generally 10 per cent or more of the total output can be recovered from the exhaust of gas engines. Even the interesting experiments of that distinguished authority, Mr. Dugald Clerk, in which he tried to improve on the working process by increasing the density of the charge before compression, have failed to effect any considerable advantage. The additional neutral gas he used, though it reduces temperatures all around, tends to retard the influx of heat, and thereby promotes after burning and heat loss through the exhaust. The combustion process pure and simple, as used in the standard types of engines (the Nuremberg, the Koerting, the Oechelhauser, the Cockerill, the Westinghouse, the Reichenbach, etc.) gives the highest economic efficiency attainable with the Otto cycle.

From the history of steam on common roads, it appears that the first steam omnibus in London was constructed and run by Hancock about the year 1840. Further developments were hindered for many years by legislation until the repeal of the "red flag" act in 1896. Steam omnibuses have been constructed on the Continent by Serpollet, De Dion, Scott, and others. About 1897 Mr. House constructed several omnibuses which were fired with liquid fuel. A service was commenced with these cars in Gloucestershire, between Fairford and Cirencester, but did not prove successful. The next steam omnibus appears to have been constructed by Messrs. Thornycroft, and was put into service on the Hammersmith route by the Road Car Company, about 1902. This car was an ordinary heavy chassis fitted with plain steel tires and fired with coke, to which a double-deck omnibus body was attached. It was commercially successful; but it was in other respects found to be unsuitable to the conditions of public service in London. In particular, the fumes and dust of the coke fuel were objectionable to the passengers, and the weight and the steel tires did not conduce to silent running. The next development in steam omnibuses appears to have been the inauguration of the service at Torquay. This was started in 1903, and the service has up to the present time worked very successfully. These cars are of the single-deck type, fired with paraffin. Similar cars were subsequently tried in London, and ran for about a year—one service by the Road Car Company, from Oxford Circus to Hammersmith, and another by the London General Omnibus Company, from Hammersmith to Piccadilly Circus. These cars had seating capacity for fourteen passengers, which did not compare favorably in earning power with the double-deck 'bus seating thirty-four passengers. Independently of the great discrepancy in their earning capacity, it is found that a distinct predilection exists among a large section of the public to "see London from the top of a 'bus." Seeing that the public taste ran parallel to the commercial interests of the omnibus companies, it was natural that the double-deck omnibus was soon selected as the best type for London service. In 1905 the first double-deck steam omnibus commenced regular service in London, and at present there are about forty licensed by the police for service in London. About one hundred of these vehicles have already been made.

SCIENCE NOTES.

So closely are all forms of knowledge related in their fundamental elements that no one of them can attain to a state of real growth without carrying others more or less with it. This elementary principle which finds illustrations and the most conclusive proof in every field of educational experience underlies the fundamental organization of the university, and it completely justifies the place of the technical school in the university plan. Further than that, it illuminates in a clear and instructive manner the natural development of the institution of universal learning.

The sun appears as bright near the middle as near the edge; so does a round hot poker. This is a consequence of the cosine law, which states that the radiation from any very small element of the luminous body varies according to the cosine of the angle between the normal to the surface and the direction in which the element is viewed. The reason the element does not radiate equally in all directions is that the radiation comes not from the surface only, but from a perceptible depth; and in oblique directions the radiation suffers most loss from absorption by the layer of substance through which it passes. If it came only from the surface there is no reason why it should not spread out equally in all directions, and in that case the sun would not appear of uniform brightness. Prof. Rutherford has recently (Philosophical Magazine), explained in this way the peculiar appearance of the image formed by the alpha stream from radioactive bodies. A wire is made radio-active by exposure to radium emanation. The alpha radiation from it is allowed to pass *in vacuo* through a very narrow slit to a photographic plate, where it makes what is essentially a "pin-hole" photograph. Now the action on the plate is most intense near the edges of this image. This effect is attributed by Rutherford to the extreme thinness of the radio-active layer taken in conjunction with the fact that the alpha particles are, on an average, projected equally in all directions. Various corroborative experiments have been made. A brass rod of square cross section is made radio-active and examined either photographically or by its action upon a screen of willemite. If the screen is placed parallel to one of the faces of the rod the appearance is that of a feebly luminous band of about the same width as the rod, bordered on each side by a more luminous region. The central region is made luminous by only one side of the rod, while the outer regions are affected by two sides. When examined photographically the edges of the central band are very sharply defined without any gradual transition of intensity from one region to the other. Still more complicated appearances are obtained by the use of a rod of hexagonal section. A sudden change of intensity occurs at every point where the tangential radiation from another side of the rod adds its effect.

The principles of agricultural chemistry, which the early investigators established, and which were collated and formed into a science by the aid of the immortal Liebig, have served as a foundation for chemists, and this basis has been sufficient to enable chemists to make great progress from the economic standpoint, so long as there were, in a sense, new worlds to conquer and new fields to cultivate, but do not fully serve when the rich stores of fertility in our fields have been, in part, exhausted. The conditions that existed here in the earlier history of our country, were not such as to demand on the part of the tiller of the soil, or farmer, a knowledge of those principles which would enable him to utilize to the best advantage soil fertility; and when the time came (as it has now for a large portion of our country), when knowledge of principles became a necessity in order that farming on these areas might be made profitable, the first duty of the chemist was to rather demonstrate the usefulness of an application of the chemical knowledge already available. That is, the chemist became a teacher, rather than an investigator, and the results of his work have been altogether good. There is now a wide knowledge of underlying principles, among the more intelligent of our farmers, mainly, however, in respect to what we now know of the relationship between the soil, the plant, and the animal. The farmer has been taught that the soil is potentially fertile, in proportion to the amount of nitrogen, phosphorus, and potassium that it contains; that the removal of crops, resulting in the carrying away of these essential elements, will ultimately exhaust his soil to such an extent as to make their further growth unprofitable, without the addition of the other elements. He has, also, learned from the chemist that a judicious utilization of crops upon the farm, and a careful handling and use of waste products, will extend the period of profitable cropping. The chemists of the country have, also, rendered incalculable service in the study of those substances which carry these elements of fertility, and which are capable of serving as food for plants, and thus developing in a remarkable degree the farmer's ability to use them in the manufacture of crops, in the sense that they may be converted into products of high commercial value. The chemists have, also, promoted the intelligent purchase and use of commercial fertilizers, by the development and improvement of methods of chemical analysis, which enable them to accurately determine the various chemical forms. They have, also, by means of field experiments, demonstrated their comparative influence in meeting soil and crop requirements, and are thus able to give safe advice as to the value of the various supplies.

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